

New Results from the XENON100 Dark Matter Search Experiment

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University College London

24th October 2012

1. Very Brief Intro to Dark Matter and Direct Detection
2. The LXeTPC & XENON100
3. Latest Results
4. The Next Generation

1. Very Brief Intro to Dark Matter and Direct Detection

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Early evidence for Dark Matter

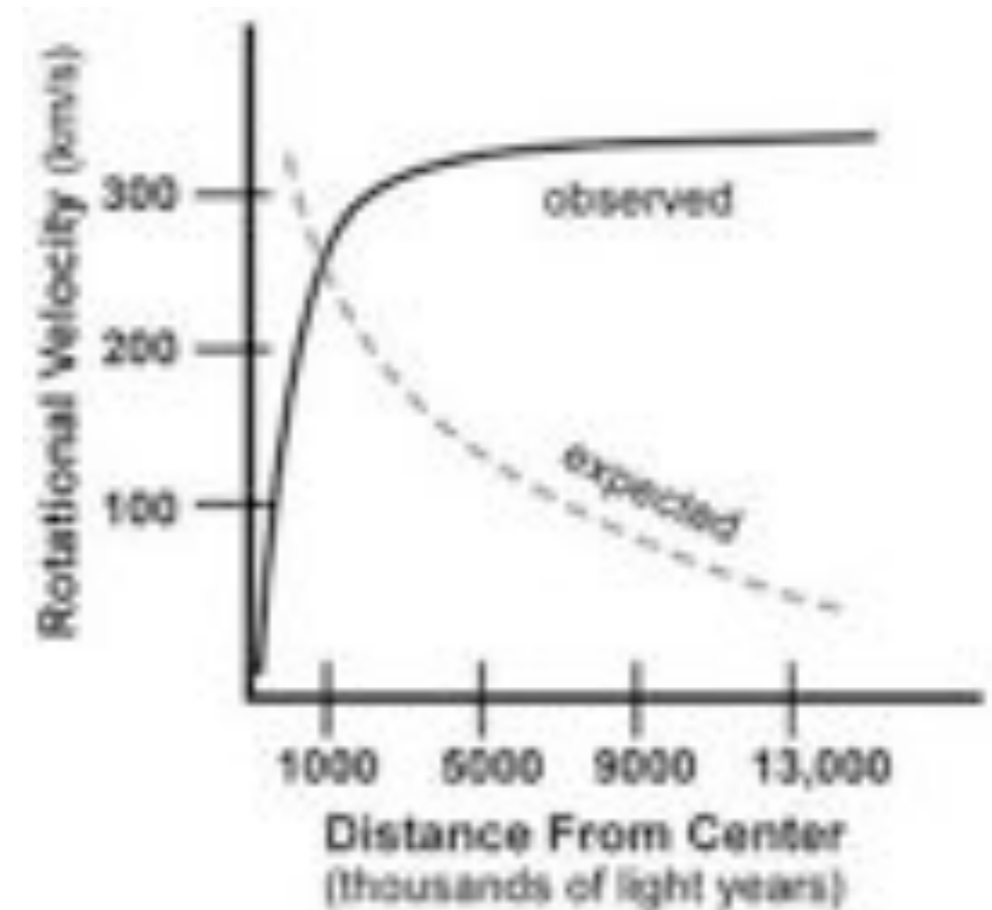
1930's - Fritz Zwicky

1970's - Vera Ruben

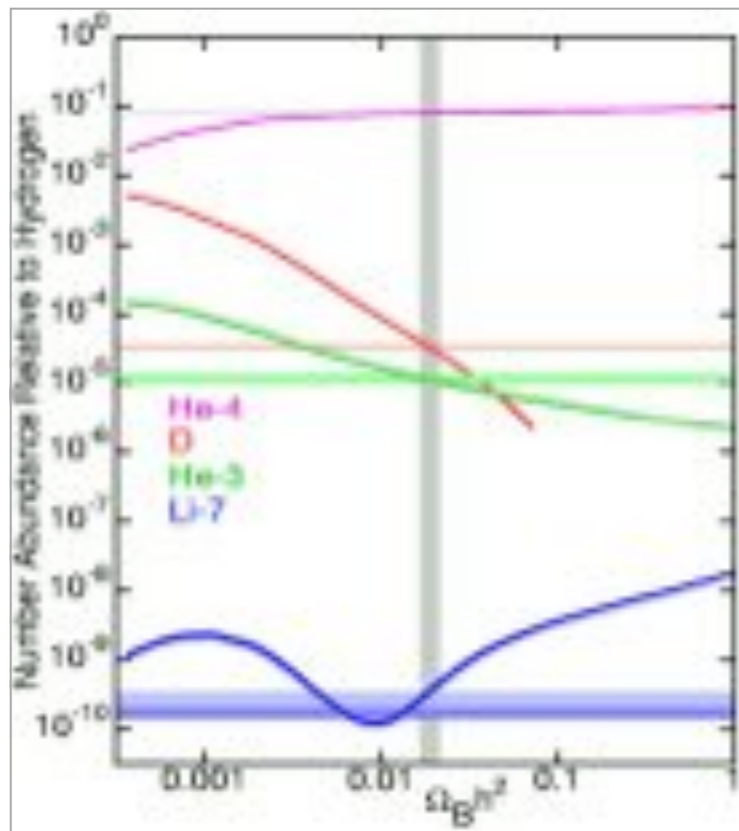
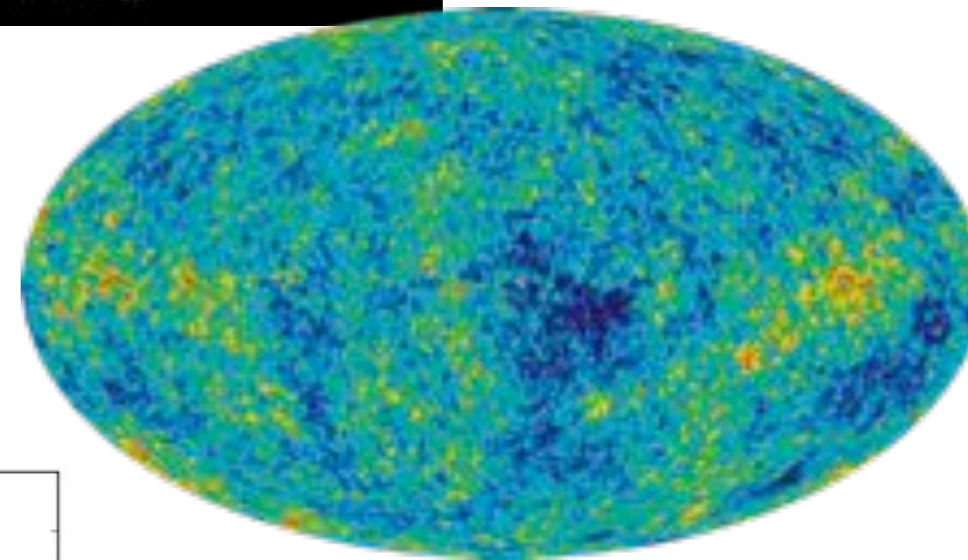
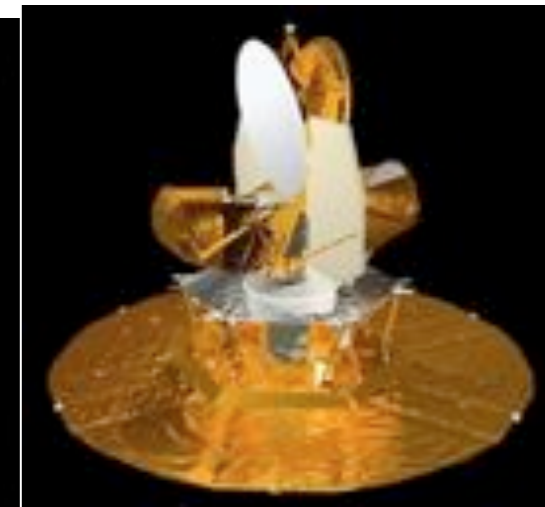
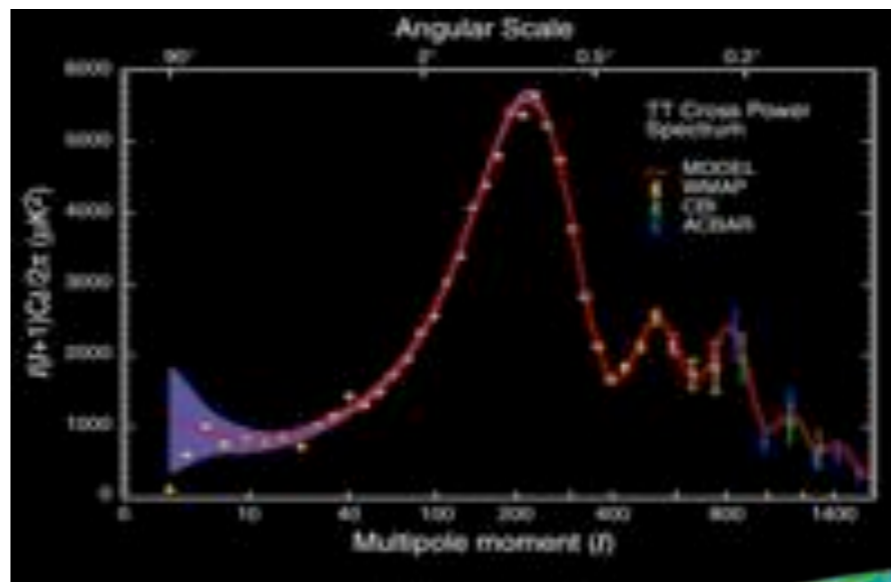
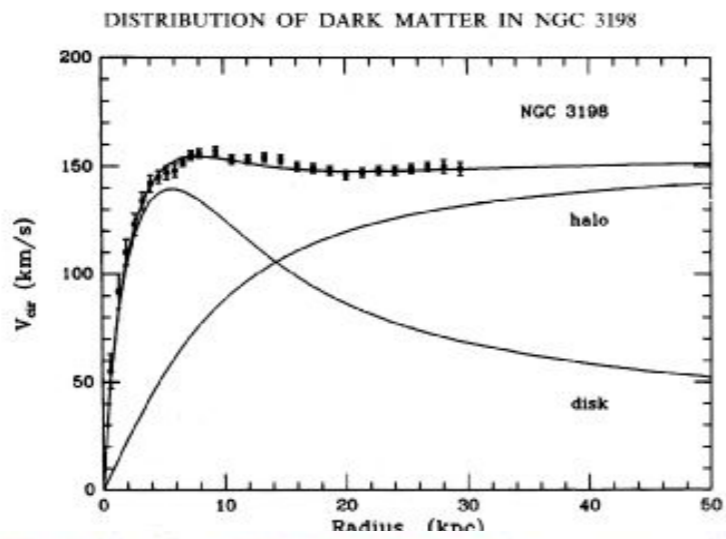
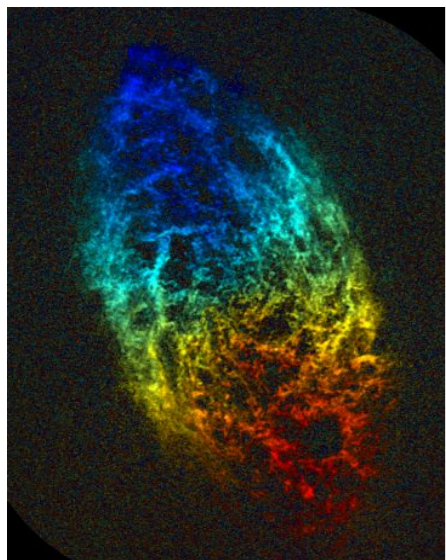
Measured rotational velocity of galaxies and observed flat curves rather than expected Keplerian fall-off with distance from galactic centre



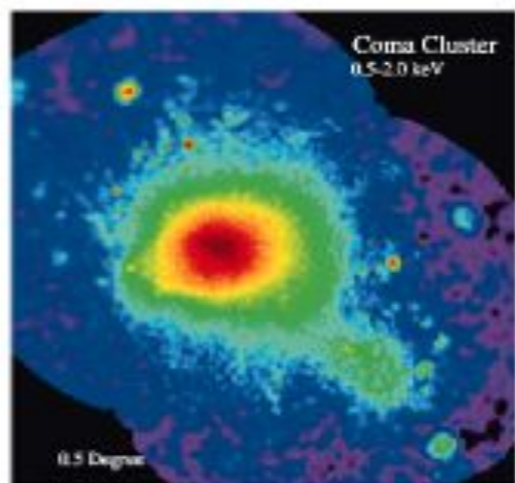
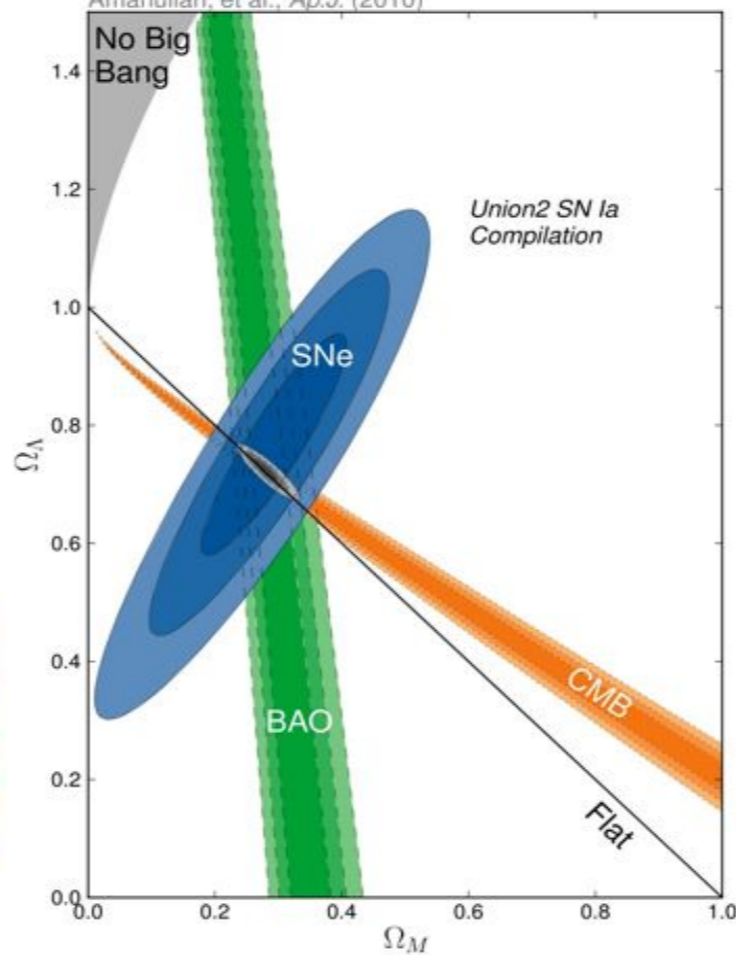
GALAXIES ARE ROTATING TOO FAST!

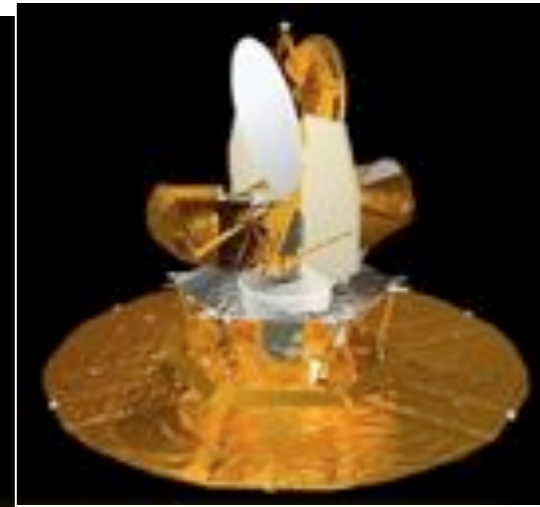
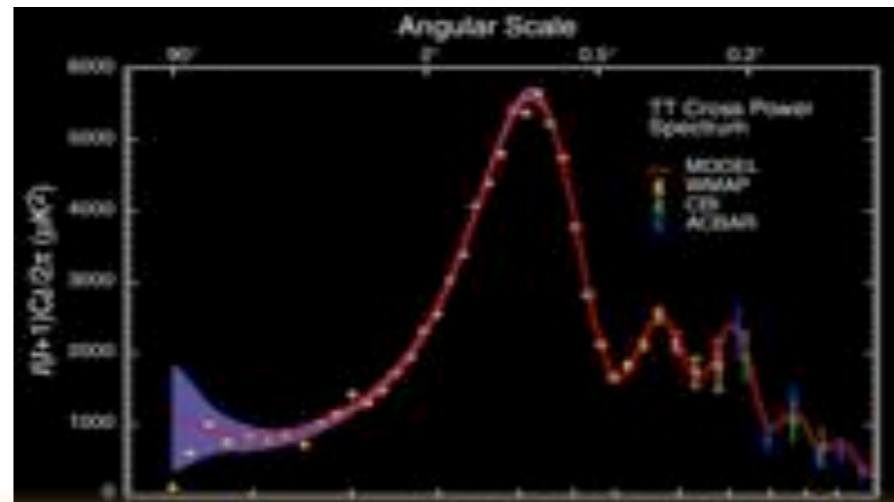
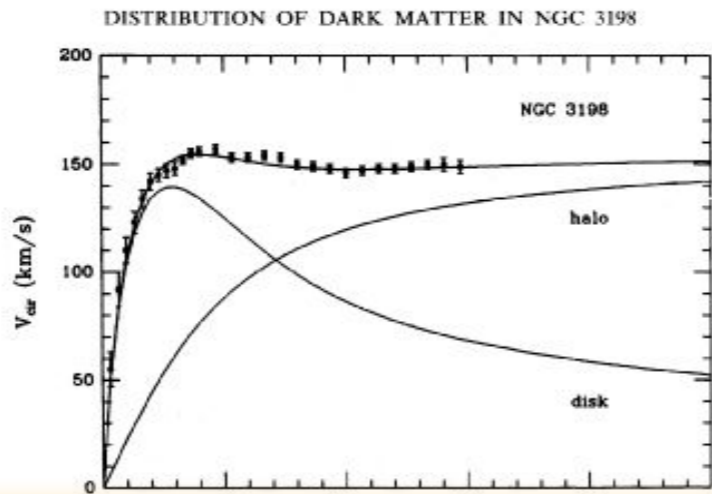
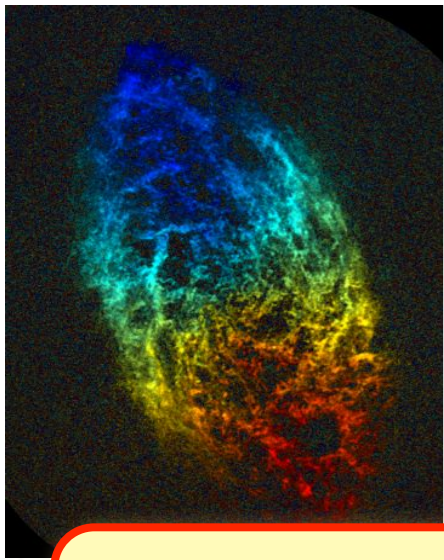


Lots more evidence since then - with little against...



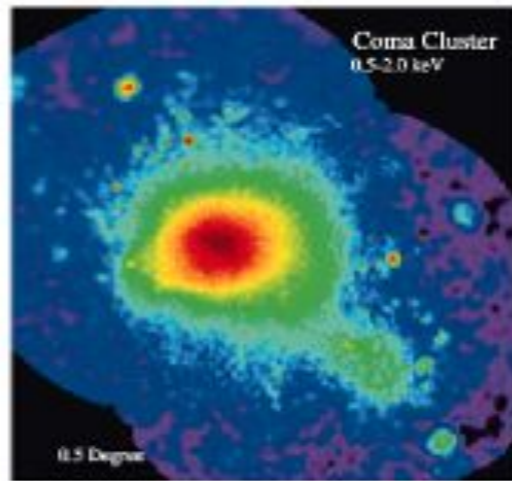
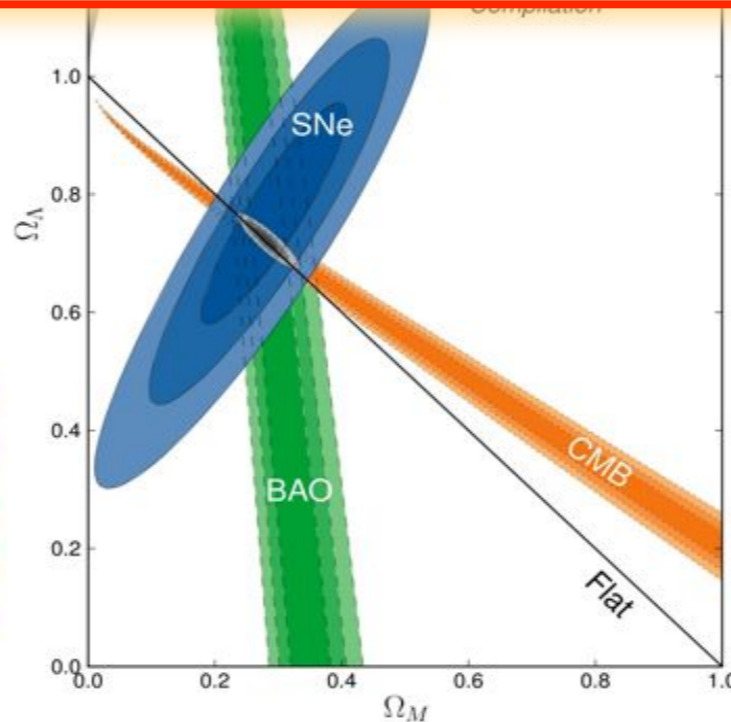
Supernova Cosmology Project
Amanullah, et al., *Ap.J.* (2010)





We have a 'Missing Mass' Problem!

85% of the mass of the Universe is **DARK!**



Dark Matter Detection

Favoured candidates are Weakly Interacting Massive Particles (WIMPs)

- Indirect - observe annihilation products
- Accelerator - produce WIMPs
- **Direct** - interact with galactic WIMPs (*our* Dark Matter!) in ultra-low background terrestrial detectors

Direct detection is internationally recognised as one of THE highest priorities in science!

ASTROPARTICLE PHYSICS

the European strategy

2. The questions of Astroparticle Physics

What is the inventory of the Universe? What is dark matter? Do protons live forever? How did neutrinos influence cosmological evolution? What is the origin of cosmic rays and what is the view of the sky at extreme energies? What will gravitational waves tell us about the Universe?

Astroparticle physics links phenomena over a vast distance scale - from the infinitesimally small world of subatomic particles to the billion light year distance of the whole Universe. It marks the intersection of cosmology, astrophysics and particle and nuclear physics. Cosmology is devoted to the very grand mysteries of the Universe. After centuries of relying on philosophical reasoning and astronomical observations, cosmology increasingly uses concepts of particle physics. Astrophysics, when exploring the most violent cosmic events, needs particle physics technologies to record the messages from these events, and particle physics theory to describe them. And particle physics, at the end, is rejuvenated by questions asked in cosmology and astrophysics, and by the most spectacular results obtained with astroparticle physics experiments.

Given the interdisciplinary approach of astroparticle physics and its overlap with astrophysics, particle physics and cosmology, a concise definition of which experiments may be considered "astroparticle physics" is difficult and perhaps not even desirable.

For the purpose of this roadmap, historical assignments used in most European countries have been adopted. Recommendations for the evolution of the field over the next decade were formulated by addressing a set of basic questions. An answer to any of these questions would mark a major breakthrough in understanding the Universe and would open an entirely new field of research on its own.

- 1) What is the Universe made of? In particular: What is dark matter?
- 2) Do protons have a finite life time?
- 3) What are the properties of neutrinos? What is their role in cosmic evolution?
- 4) What do neutrinos tell us about the interior of the Sun and the Earth, and about supernovae explosions?
- 5) What is the origin of cosmic rays? What is the view of the sky at extreme energies?
- 6) What will gravitational waves tell us about violent cosmic processes and about the nature of gravity?

The following chapters describe the tools to address these questions.

The questions for dark matter have been derived by the Dark Matter Task Group in 2002, after evaluation of the numerous proposals in larger studies. In the meantime, the experimental status of galaxies suggests that 20% of some galaxies is made from invisible matter.



<http://www.aspera.eu.org>

Connecting Quarks with the Cosmos

Eleven Science Questions for the New Century

Committee on the Physics of the Universe
Board on Physics and Astronomy
Division on Engineering and Physical Sciences
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

following decades. Among them are the most profound questions that human beings have ever posed about the cosmos. The fact that they are ripe now, or soon will be, further highlights how exciting the possibilities of this moment are. The 11 questions are these:

What is Dark Matter?

Astronomers have shown that the objects in the universe, from galaxies a million times smaller than ours to the largest clusters of galaxies, are held together by a form of matter different from what we are made of and that gives off no light. This matter probably consists of one or more as-yet-undiscovered elementary particles, and aggregations of it produce the gravitational pull leading to the formation of galaxies and large-scale structures in the universe. At the same time these particles may be streaming through our Earth-bound laboratories.

THE NATIONAL ACADEMIES PRESS
Washington, D.C.



Science & Technology
Facilities Council

Science Roadmap

- STFC Home
- Roadmap Home
- Science Challenges list
- Project list
- Navigator

Science Challenges

The Science Roadmap is built around the following key science questions:

A: How did the universe begin and how is it evolving?



- A:1. What is the physics of the early universe?
- A:2. How did structure first form?
- A:3. What are the roles of dark matter and dark energy?
- A:4. When were the first stars, black holes and galaxies born?
- A:5. How do galaxies evolve?
- A:6. How are stars born and how do they evolve?

B: How do stars and planetary systems develop and is life unique to our planet?



- B:1. How common are planetary systems and is ours typical?
- B:2. How does the Sun influence the environment of the Earth and the rest of the Solar System?
- B:3. Is there life elsewhere in the universe?

C: What are the fundamental constituents and fabric of the universe and how do they interact?



- C:1. What are the fundamental particles?
- C:2. What is the nature of space - time?
- C:3. Is there a unified framework?
- C:4. What is the nature of dark matter?
- C:5. What is the nature of dark energy?
- C:6. What is the nature of nuclear and hadronic matter?
- C:7. What is the origin of the matter - antimatter asymmetry?

D: How can we explore and understand the extremes of the universe?

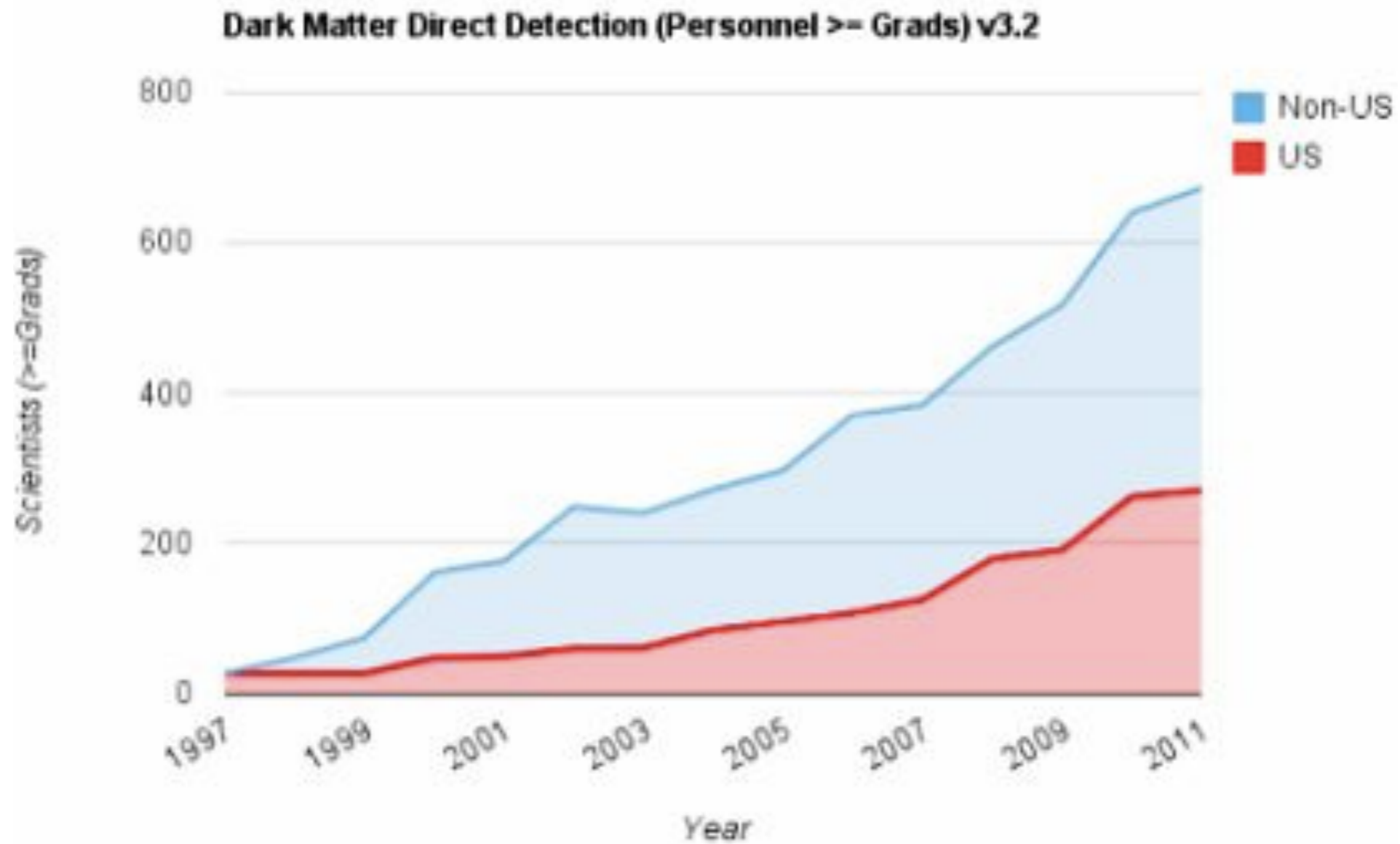


- D:1. How do the laws of physics work when driven to the extremes?
- D:2. How can high energy particles and gravitational waves tell us about the extreme universe?
- D:3. How do ultra-compact objects form, what is their nature and how does extreme gravity impact on their surroundings?

We welcome your feedback on this new utility

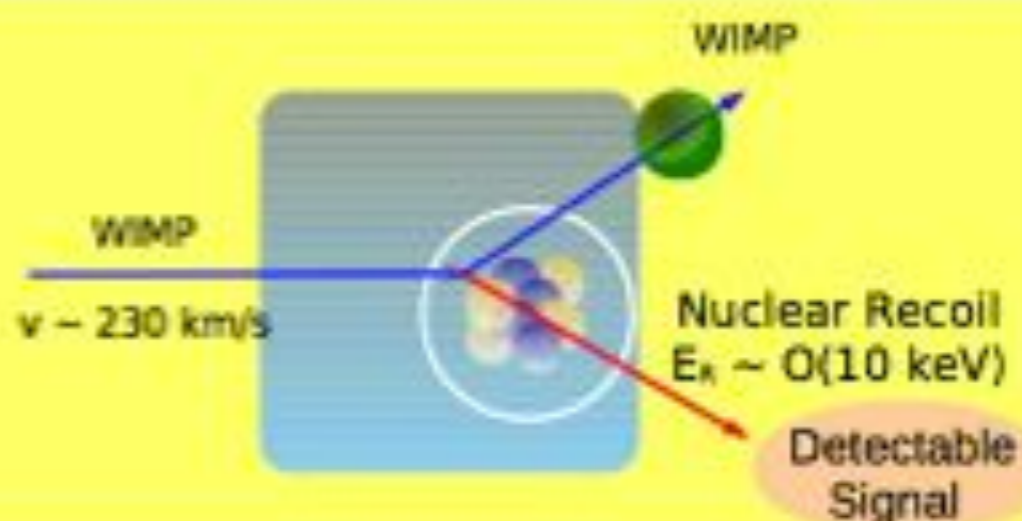
High Priority on just about all Roadmaps and Influential Advisory Documents

A Growing Field



Direct WIMP Search

Elastic Scattering of WIMPs off target nuclei
 → nuclear recoil

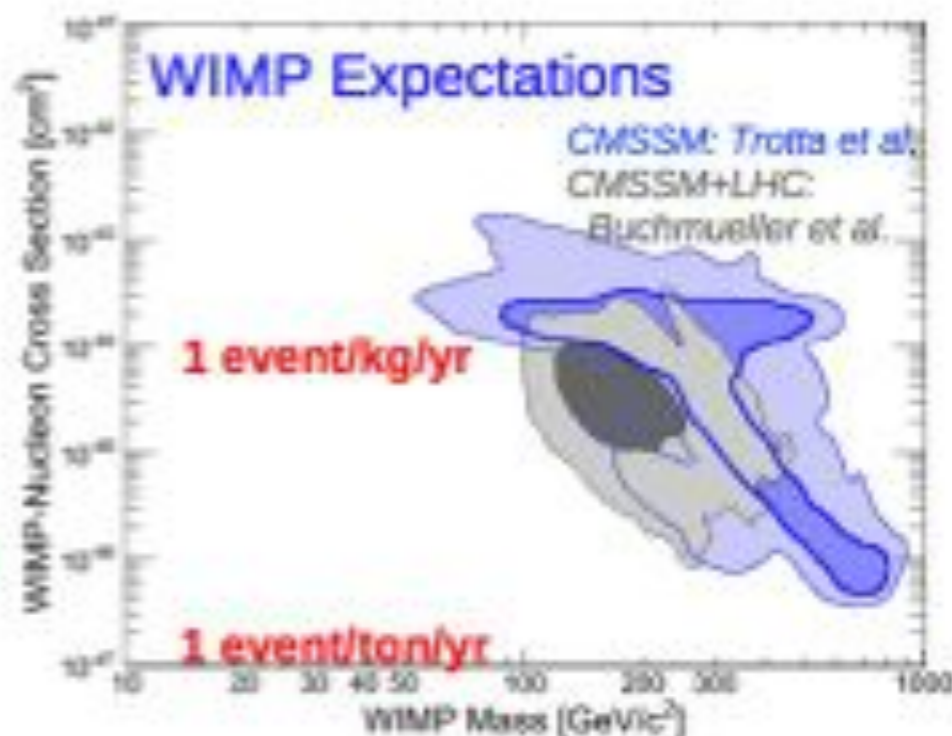


Recoil Energy: $E_r \sim \mathcal{O}(10 \text{ keV})$

Event Rate: $R \propto N \frac{\rho_\chi}{m_\chi} (\sigma_{\chi-N})$

Detector Local DM Density Physics

$\rho_\chi \sim 0.3 \text{ GeV}/c^3$



WIMP Detection Techniques

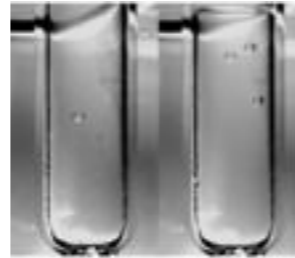
Heat and ionisation bolometers:

CDMS
EDELWEISS



Bubbles and Droplets:

CUOPP
PICASSO



Light and heat Bolometers:

CRESST
ROSEBUD

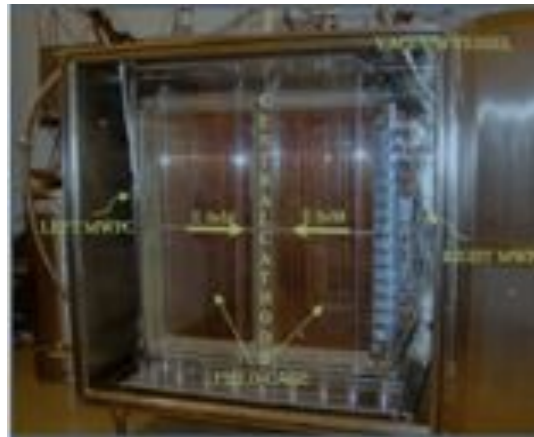


Phonons



Charge

Light

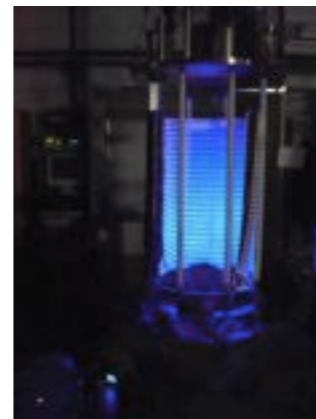


Ionisation detectors:

DRIFT, DMTPC, GENIUS, NEWAGE,
HDMS, IGEX

Scintillation and ionisation charge detectors:

XENON
DarkSide
ZEPLIN
LUX



Scintillators:

DAMA
LIBRA
XMASS
CLEAN
DEAP
ANAIS
KIMS



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Liquid Xenon Time Projection Chambers

- **S1: LXe is an excellent scintillator**

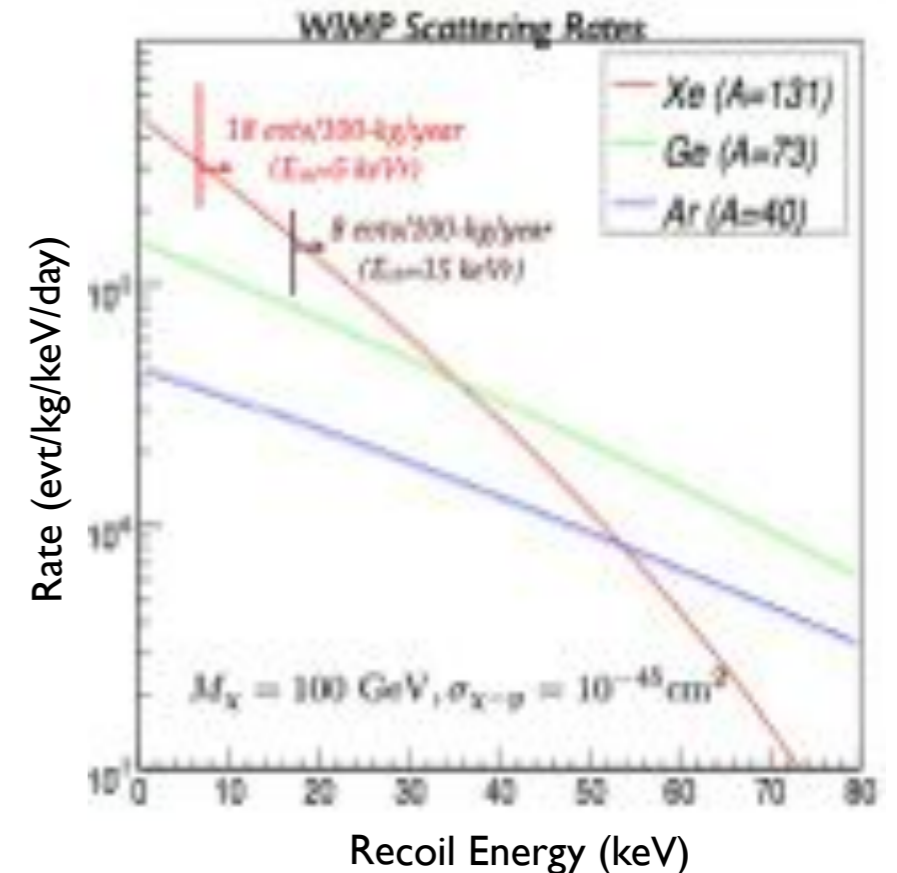
- Density: 3 g/cm³
- Light yield: >60 ph/keV (0 field)
- Scintillation light: 178 nm (VUV)
- **Nuclear recoil threshold ~5-8 keV**

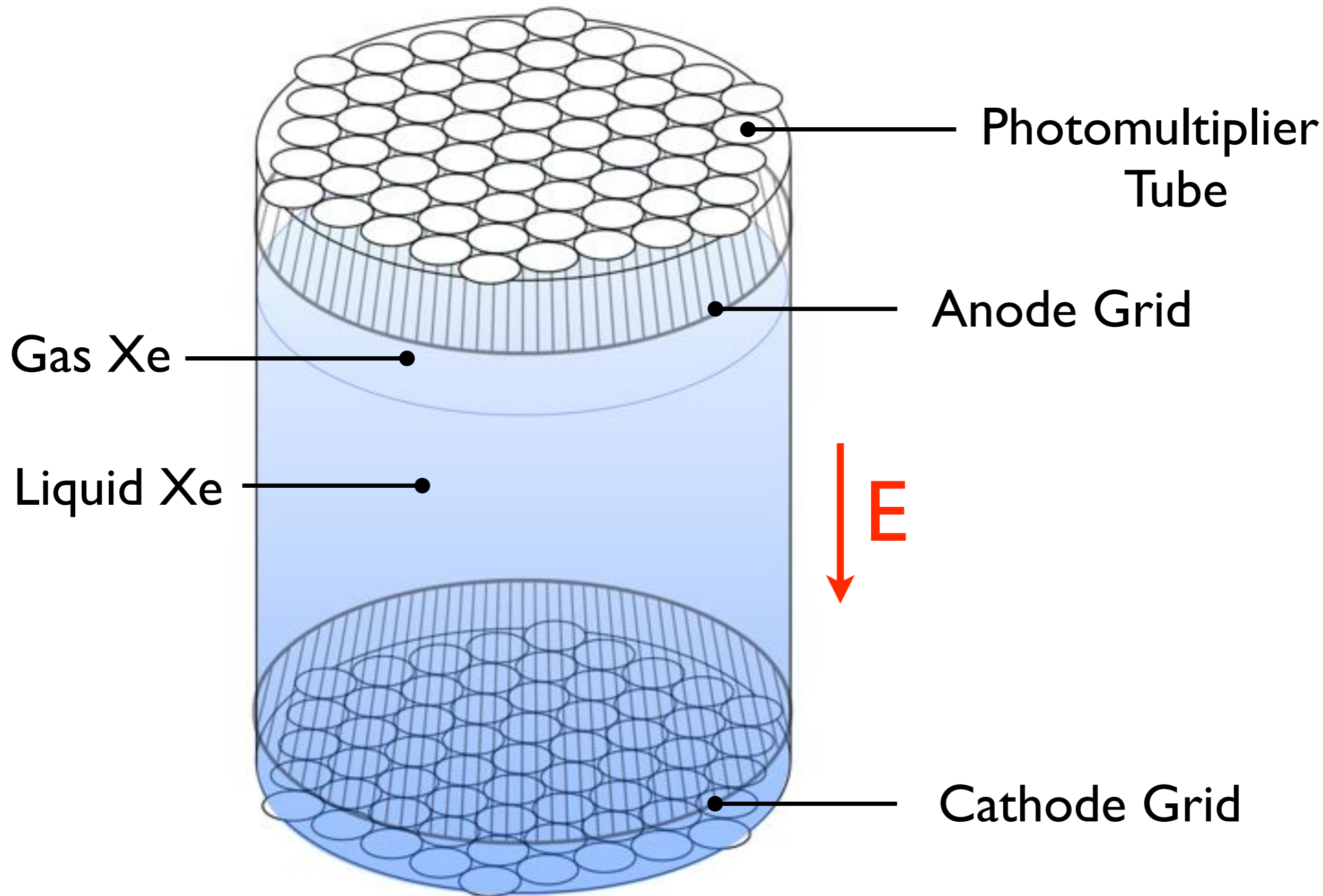
- **S2: Even better ionisation detector**

- S1+S2 allows mm vertex reconstruction
- Sensitive to single ionisation electrons
- **Nuclear recoil threshold ~1 keV**

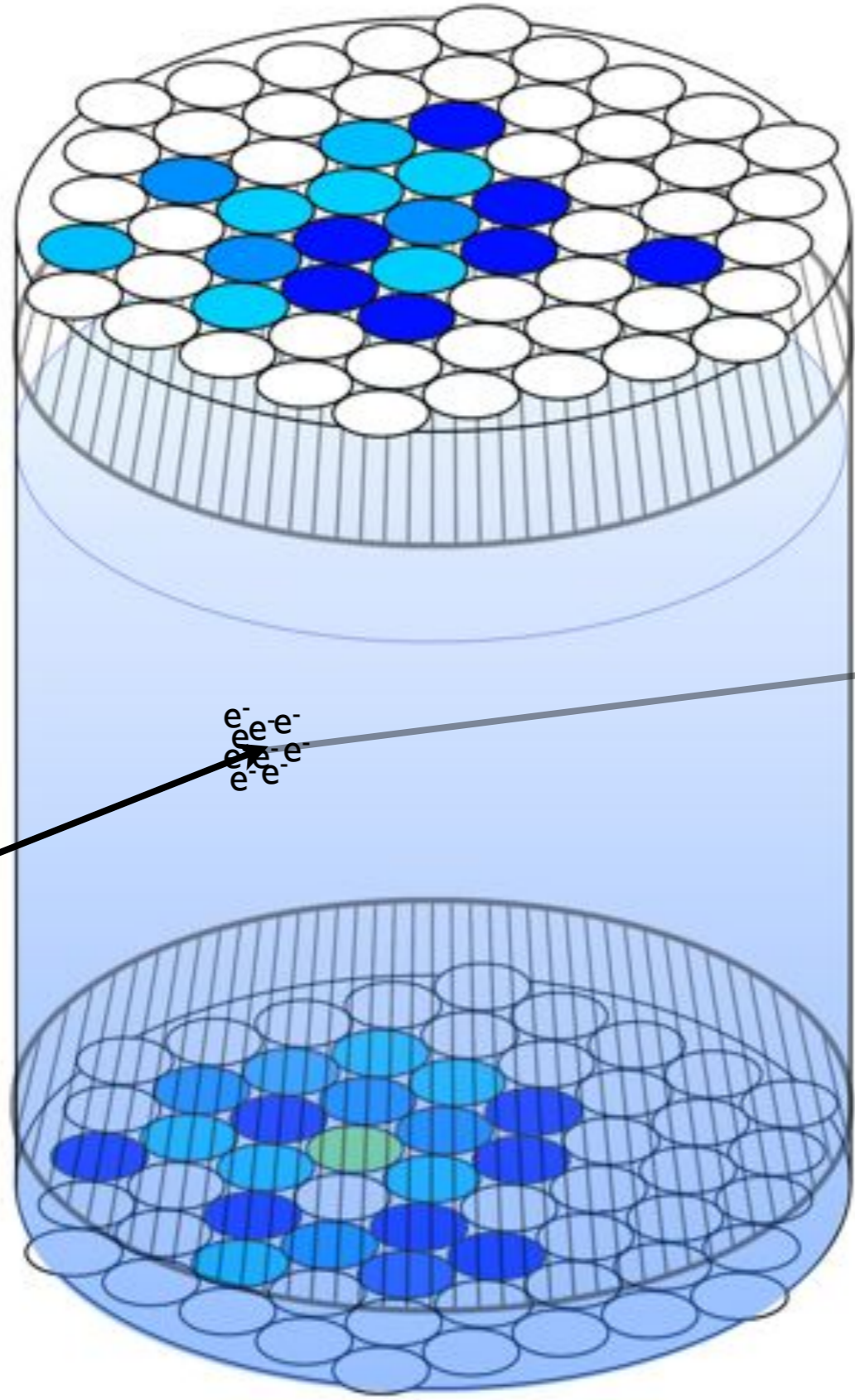
- **And a great WIMP target too**

- Scalar WIMP-nucleon scattering rate $dR/dE \sim A^2$
- Odd-neutron isotopes (¹²⁹Xe, ¹³¹Xe) enable spin-dependent sensitivity
- Excellent ionisation threshold: ‘light WIMP’ searches using S2 only
- No intrinsic backgrounds (⁸⁵Kr can be removed, low rate from ¹³⁶Xe $2\nu\beta\beta$)
- Easily scaled with no loss of performance (actually improves!)

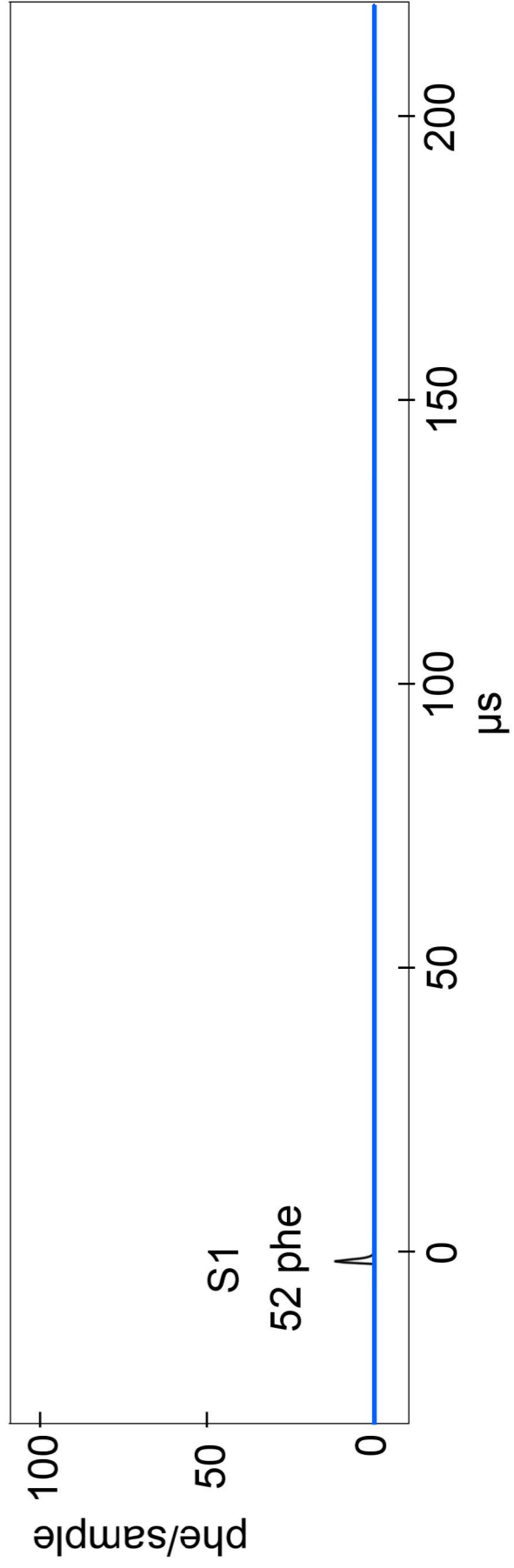




S1

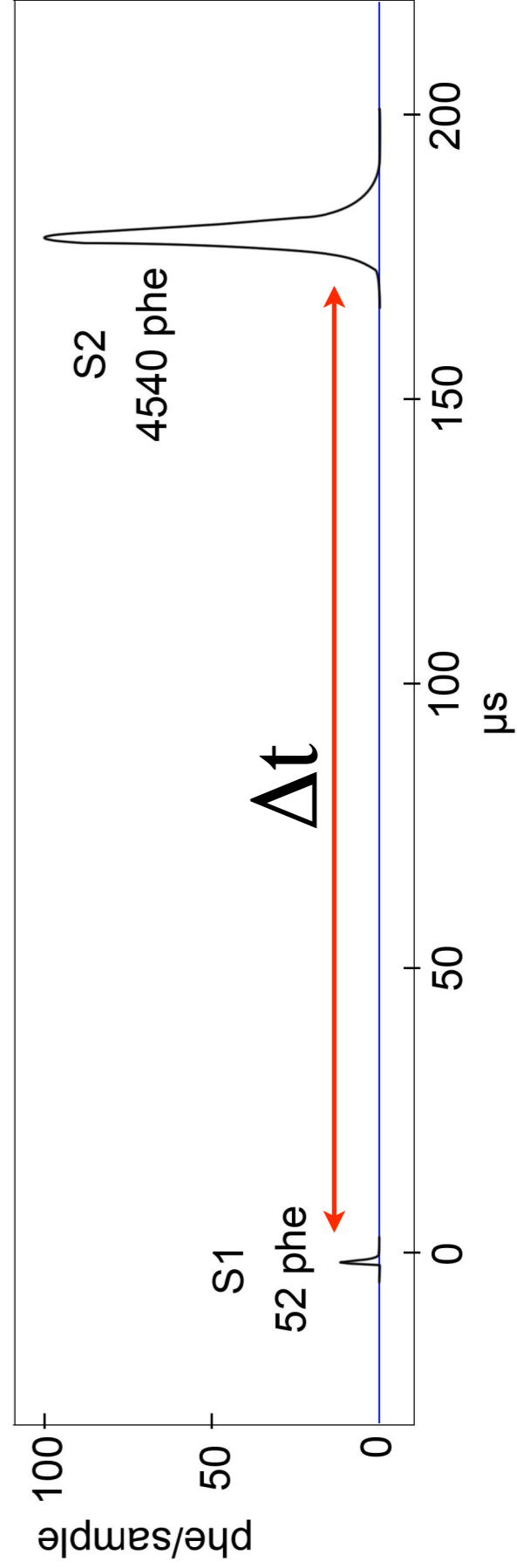
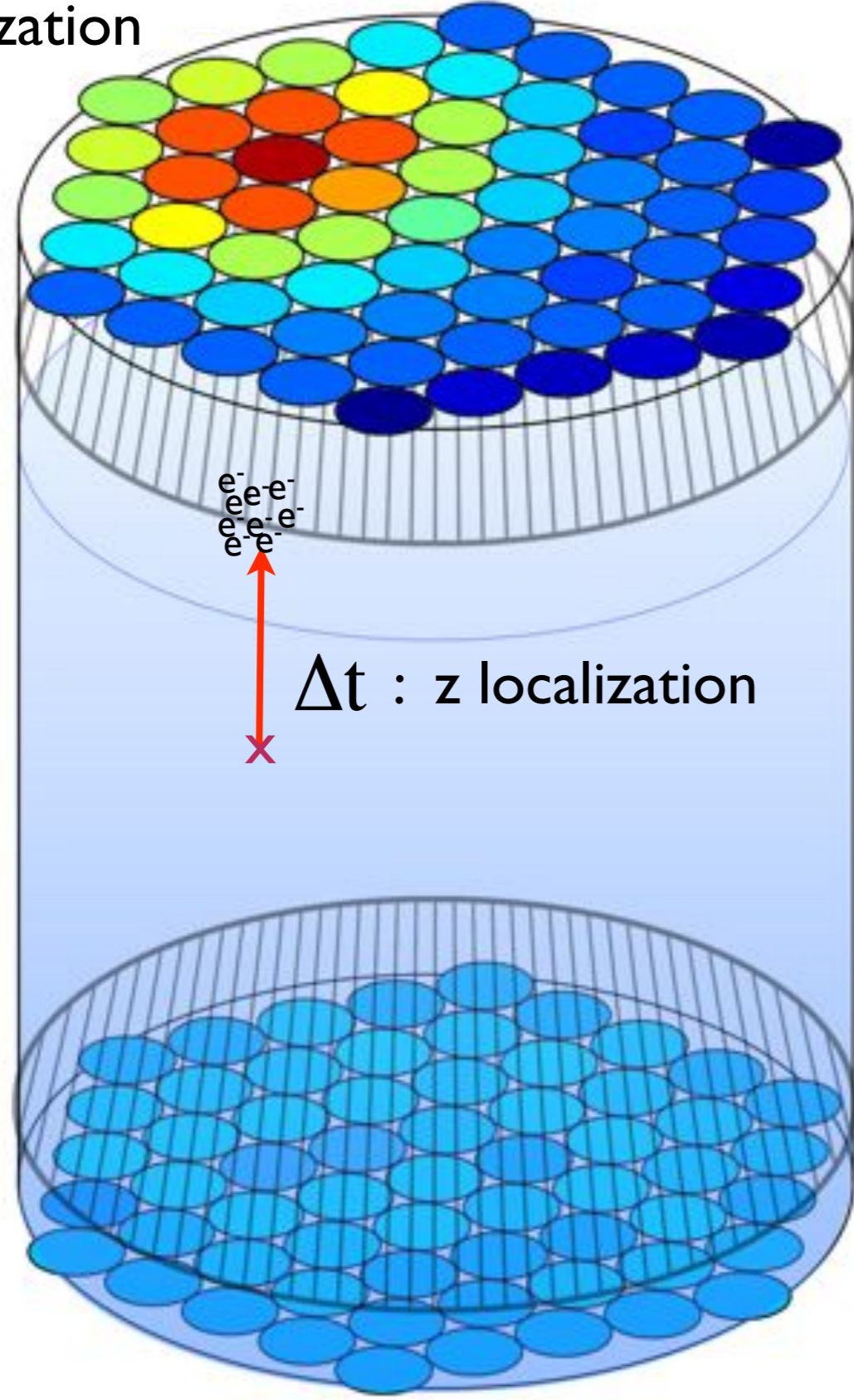


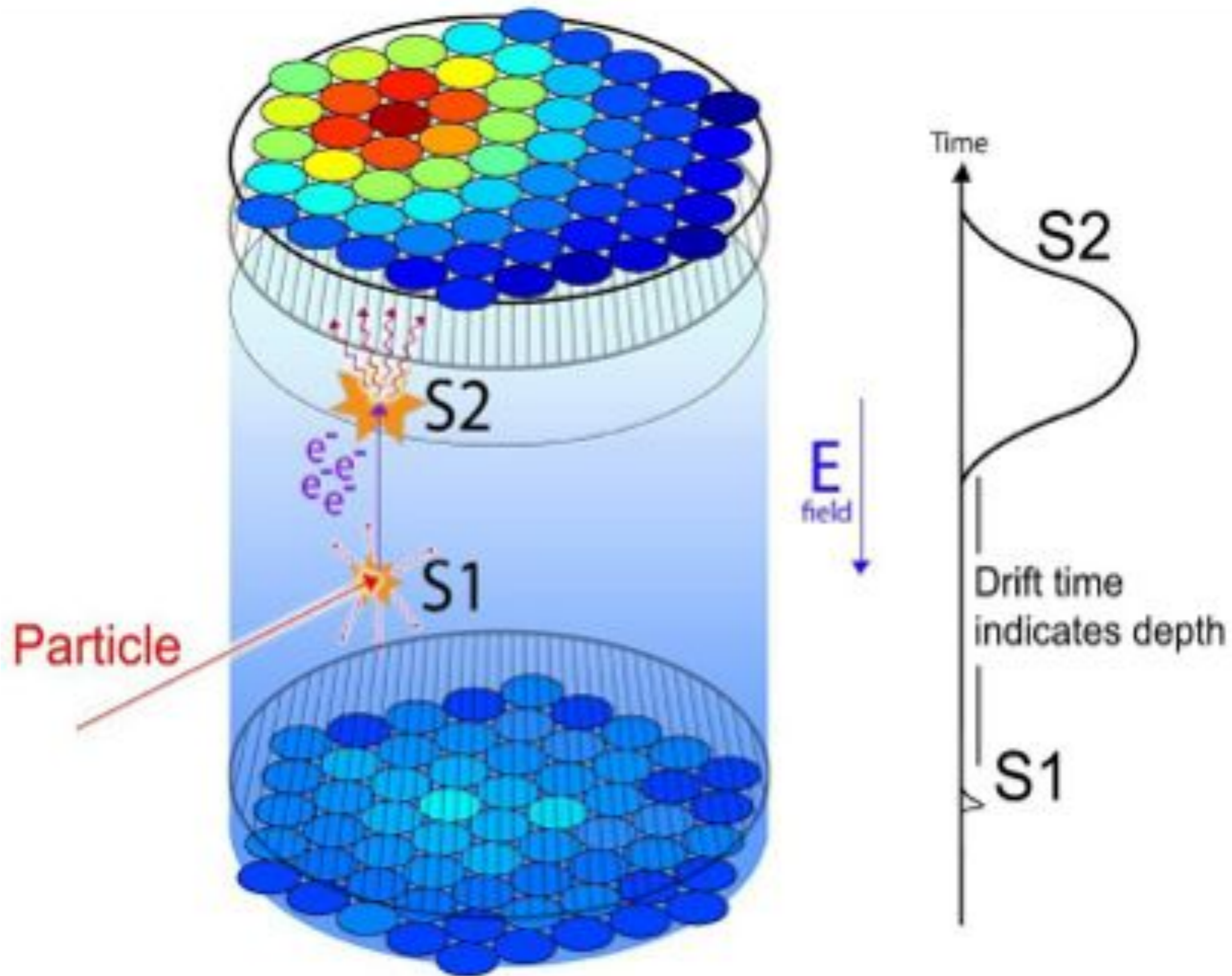
e⁻
e⁻
e⁻
e⁻
e⁻





S2

top hit pattern:
x-y localization



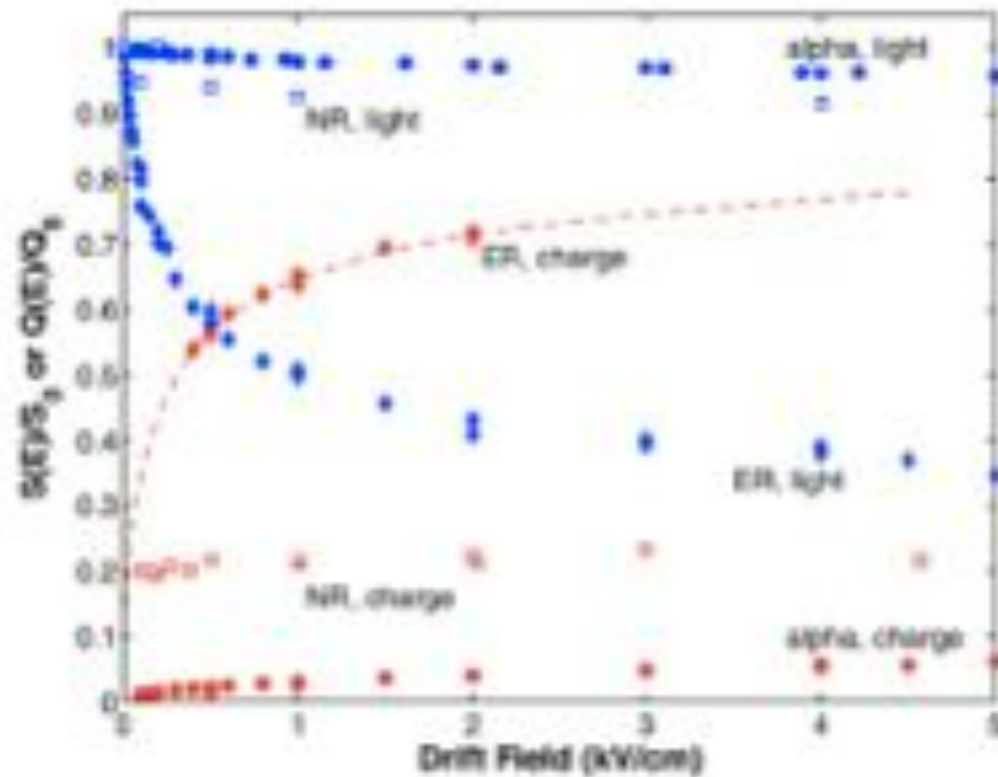


-  ionization electrons
-  UV scintillation photons (~175 nm)

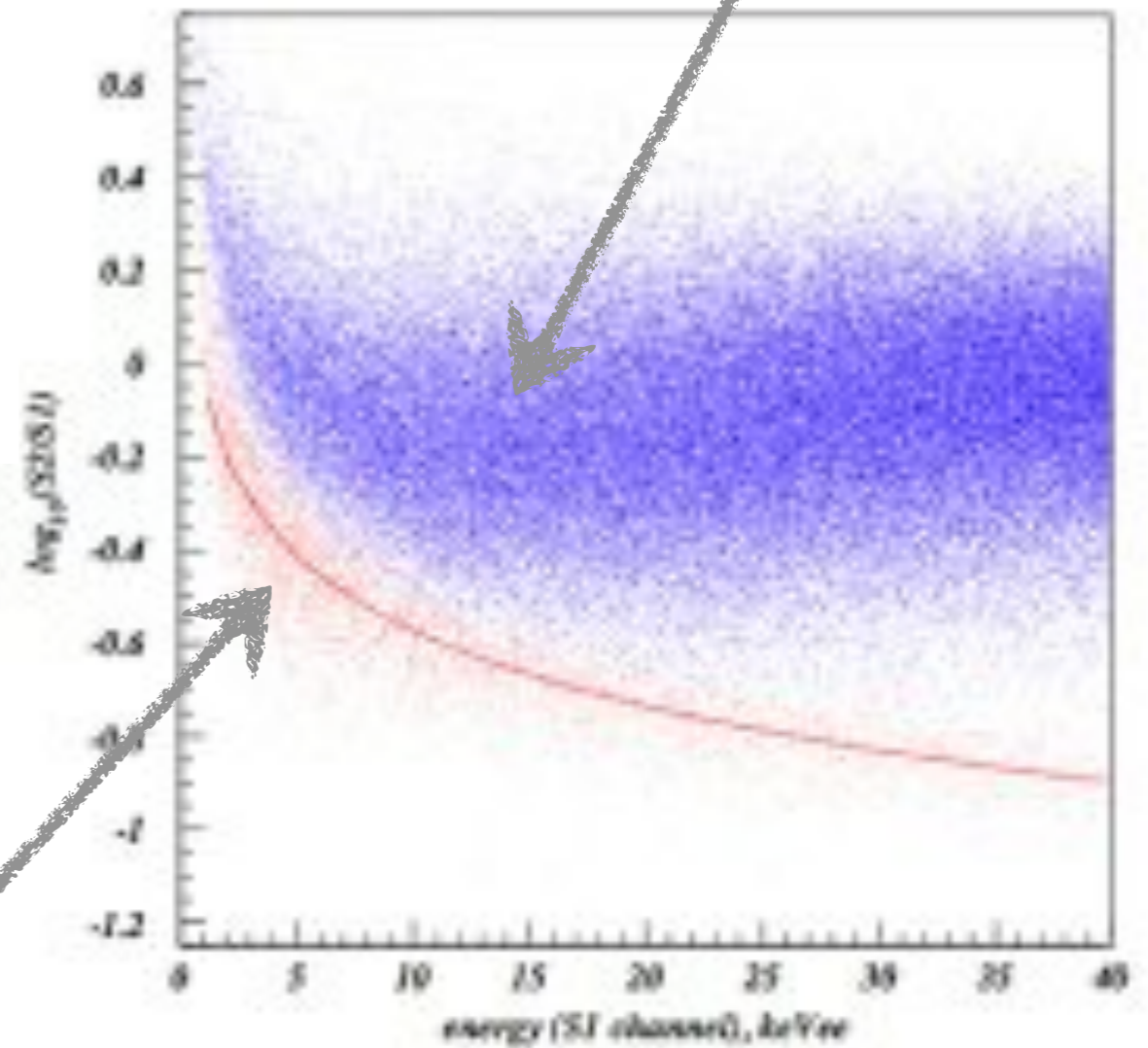
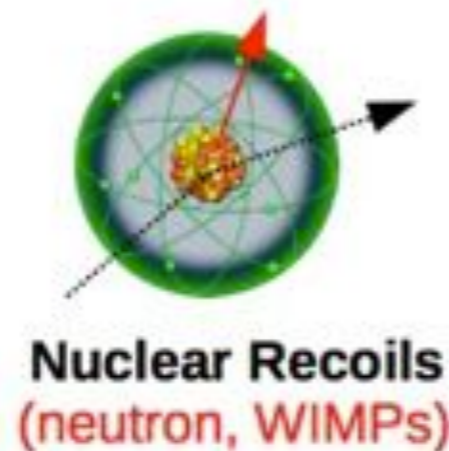
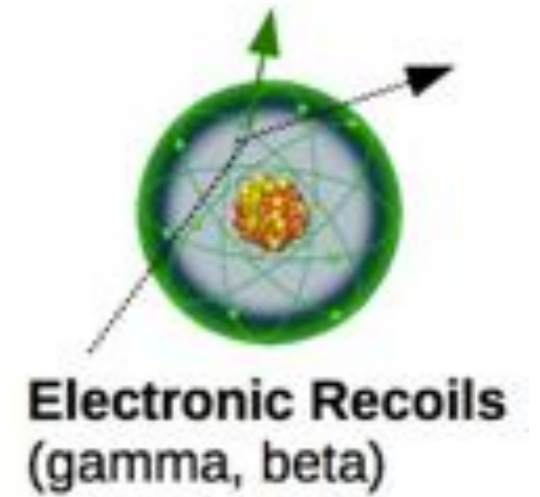
WIMP Signals in a Dual-Phase Xenon Detector



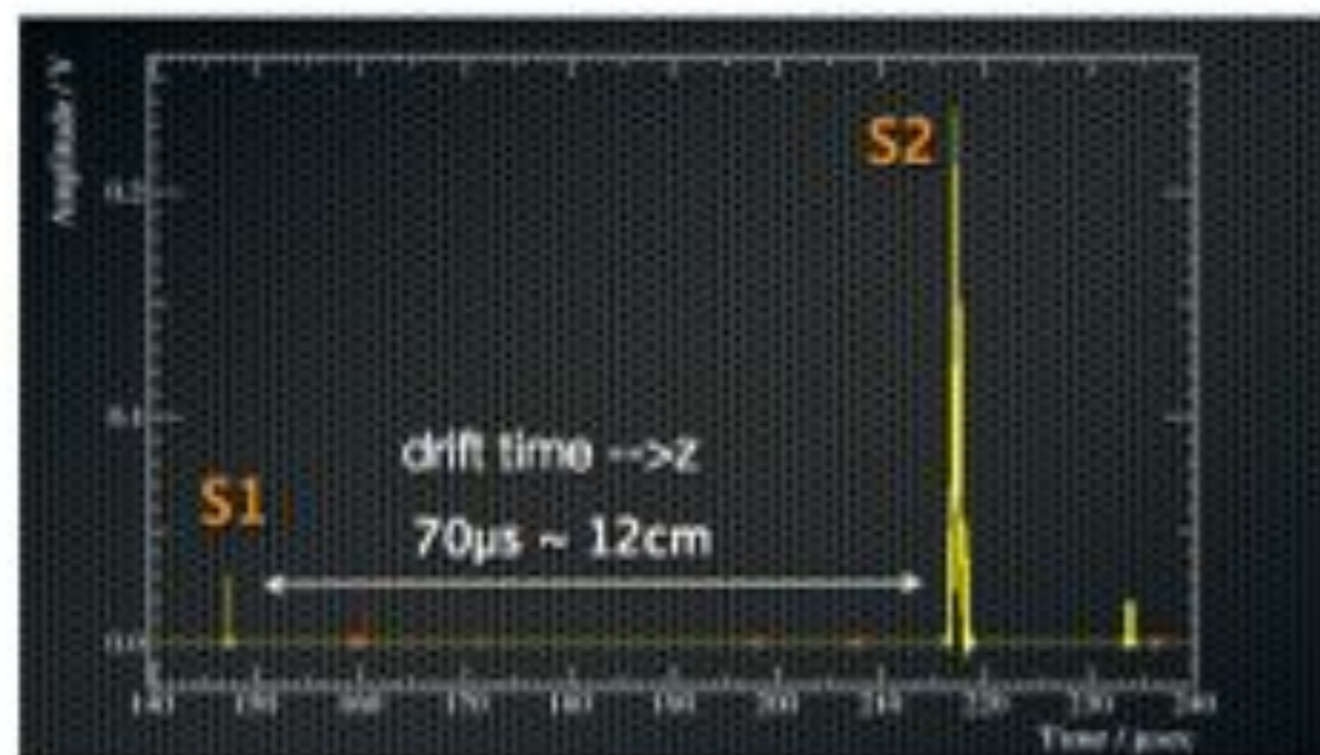
Particle Discrimination



Light (S1) and charge (S2) depend on recoil dE/dx



Event Position Reconstruction



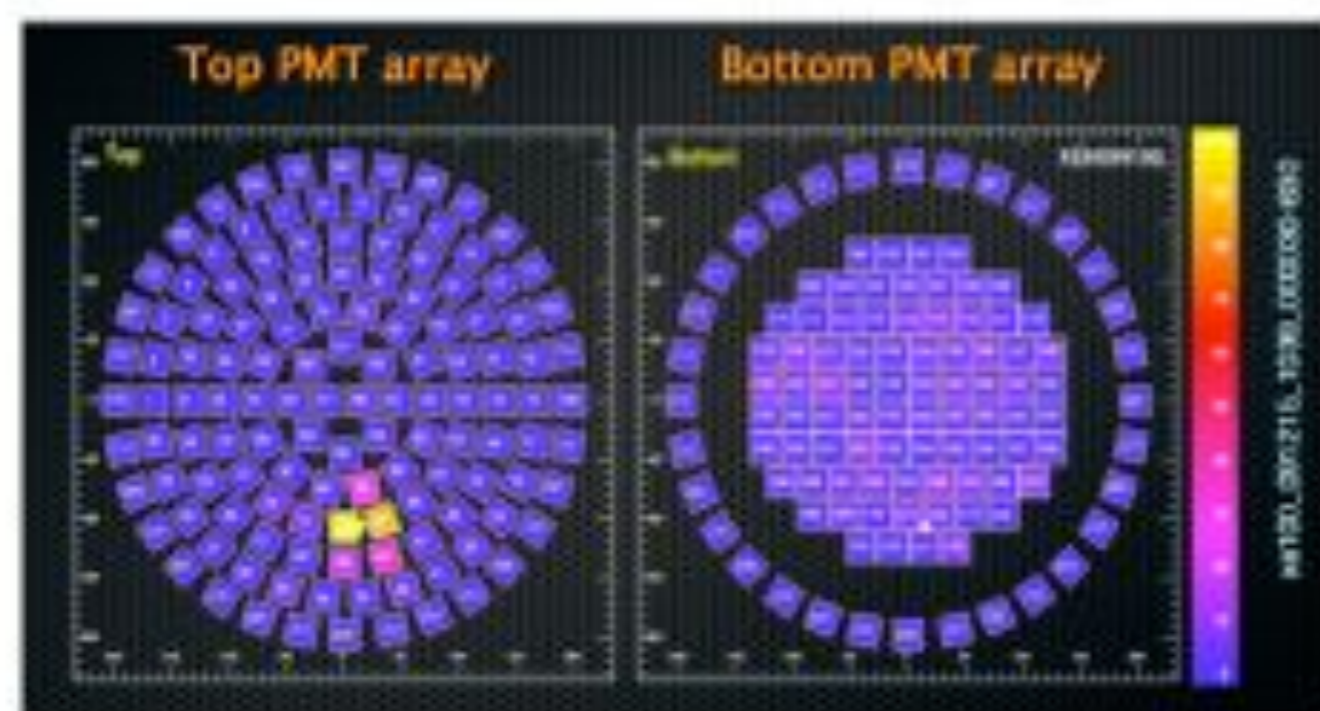
Example of a low energy (9 keVnr)

4 photoelectrons detected from about 100 S1 photons

645 photoelectrons detected from 32 ionization electrons which generated about 3000 S2 photons

Event Z-position from measured drift time $t(\text{S2}) - t(\text{S1})$ and known e^- velocity. $dZ < 0.3 \text{ mm}$

event X-Y position from measured S2-hit-pattern. $dR < 3\text{mm}$



The XENON Roadmap

XENON10



2005-2007

PRL100
PRL101
PRL 107
PRD 80
NIM A 601

XENON100



2007-2013

first results:
PRL105, PRL107, PRD84

XENON1T



2012-2017

approved at LNGS, Hall B
construction starts in fall 2012

- Gradually increasing the WIMP target mass while decreasing the background level

The XENON Collaboration

Columbia, Zürich, Coimbra, Mainz, LNGS, WIS, Münster, MPIK, Subatech, UCLA, Bologna, Torino, Nikhef, Purdue

XENON meeting at LNGS, April 2012



Columbia



Rice



UCLA



Zürich



Coimbra



LNGS



SJTU



Mainz



Bologna



Subatech



Münster



Nikhef



Heidelberg

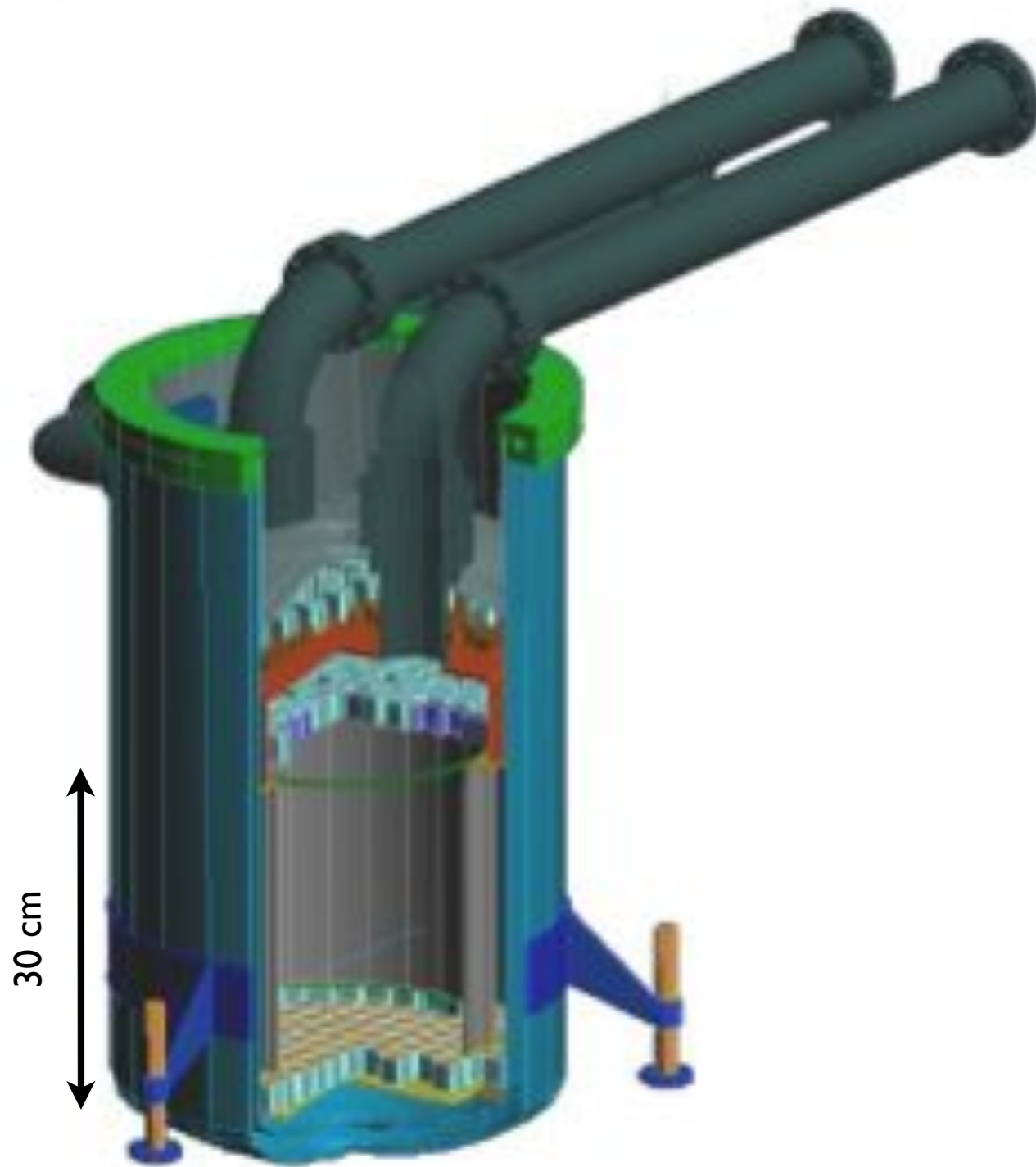


Weizman



PURDUE
UNIVERSITY
Purdue

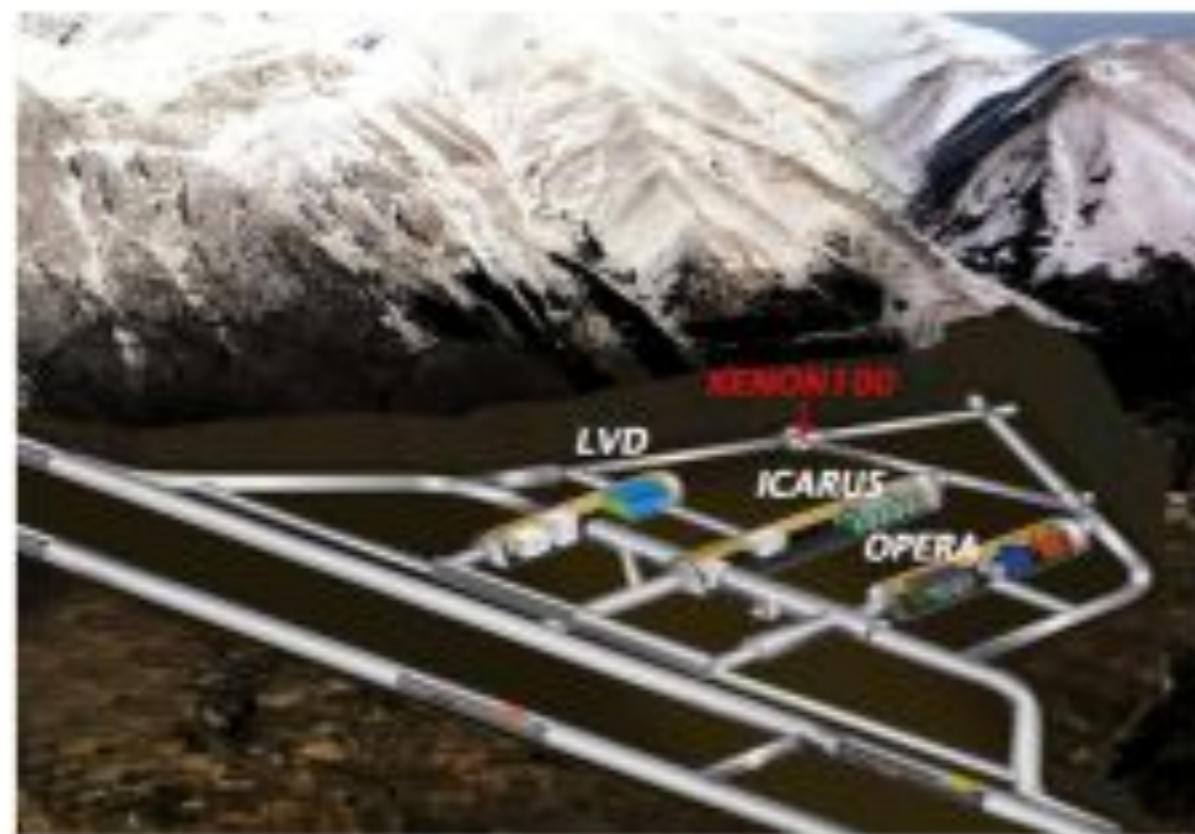
The XENON100 detector overview



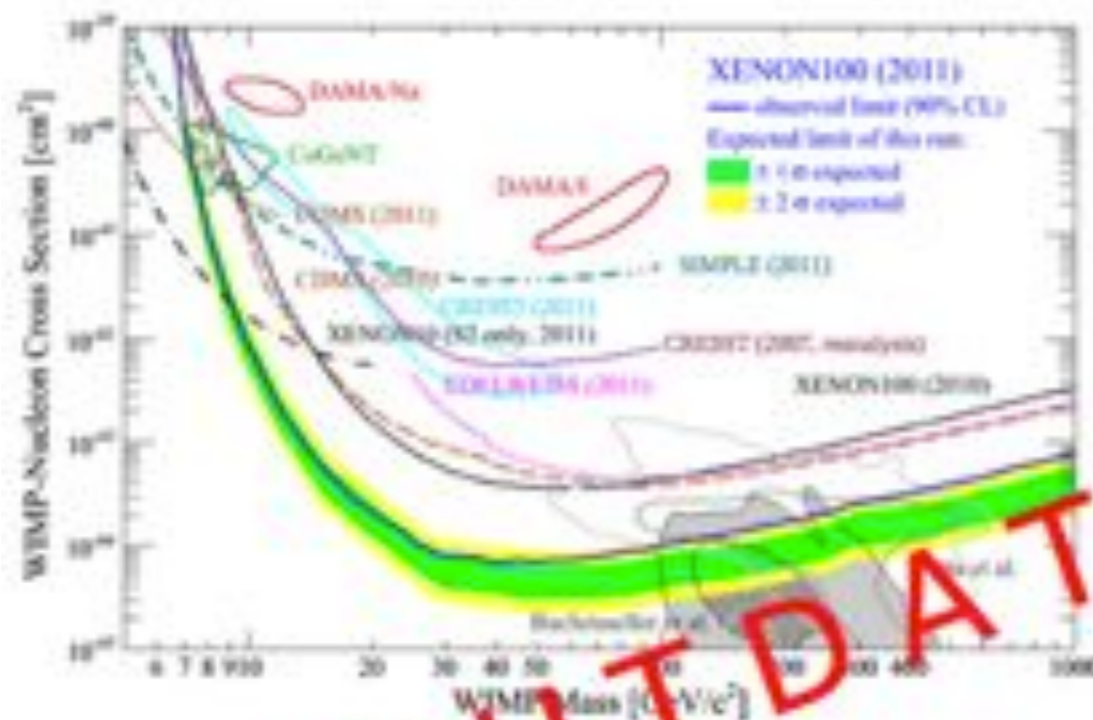
- 100 x less background than XENON10
- 10 x more fiducial mass than XENON10
- Cryocooler and FTs outside shield
- Materials screened for low radioactivity
- LXe scintillator active veto system
- Improved passive shield system
- Dedicated Kr distillation column
- TPC with 30 cm drift x 30 cm diameter
- 161 kg ultra pure LXe - 62 kg as target
- 1" square PMTs with ~ 1 mBq (U/Th)

XENON100 Location and Shield

- LNGS provides the shield against cosmic rays: 1.4 km of mountain
- Passive shield:
 - ⇒ 5 cm (2 tons) of Cu, 20 cm (1.6 tons) of PE, 20 cm (33 tons) of Pb, plus 20 cm water shield
- Detector housing is continuously purged with boil-off N_2 , to maintain a radon level $< 0.5 \text{ Bq/m}^3$
- All materials screened with HPGe detectors at LNGS see *Astroparticle Physics* 35, 2011



(spin-independent) WIMP Limit 2011

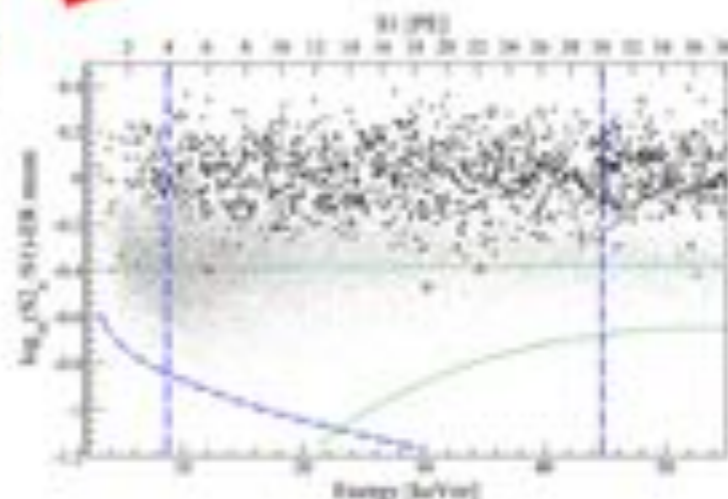


XENON100 sets the most sensitive limit over a large WIMP mass range
Challenges the CoGeNT, DAMA, CRESST-II signals as being due to light mass WIMPs

PRL 107, 131302 (2011)

already cited 362x

Limit derived with
Profile Likelihood method
PRD 84, 052003 (2011)



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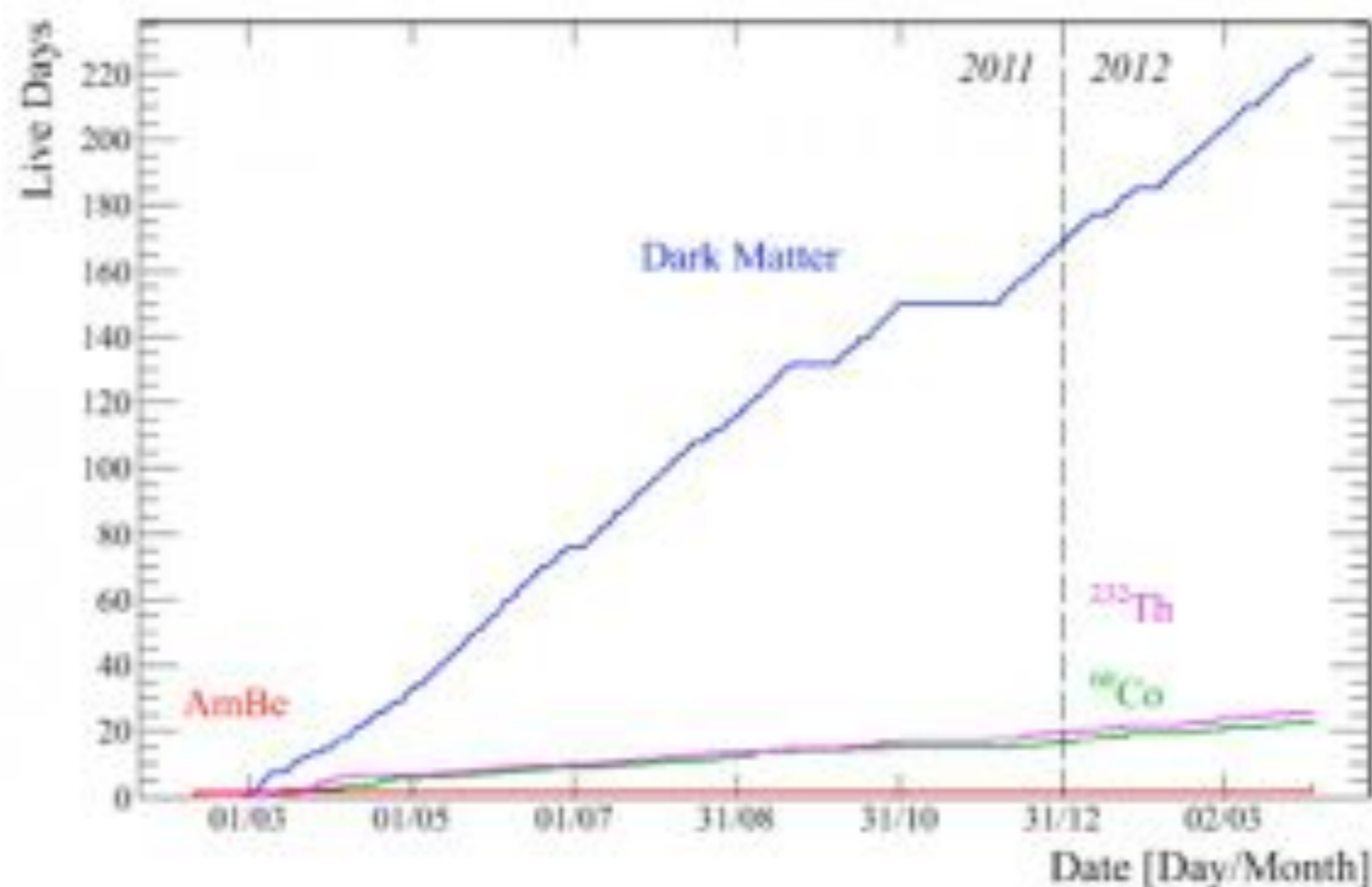
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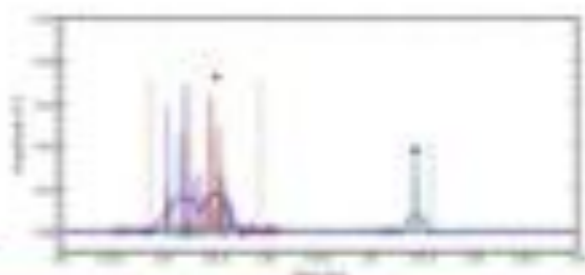
4. The Next Generation

New XENON100 Dark Matter Search: Run 10

- Data taking period: February 2011 - March 2012
- 224.56 live days of dark matter data
- 48 live days of ^{60}Co and ^{235}Th calibration data; 2 AmBe runs (beginning/end of science run)



From raw waveforms to results



Majority trigger, efficiency > 99% for $S2 > 150$ pe

Data acquisition: sample PMT traces @ 100 MS/s in windows around signals > 0.35 pe



PMT waveforms



Raw data processing, baseline and noise measurement; S1, S2 signal recognition; signal integration; position reconstruction; signal correction (gain, spatial)



root trees



Physics analysis input: astrophysics, nuclear physics, DM data sidebands, NR and ER calibration => response, background estimate

reduced data

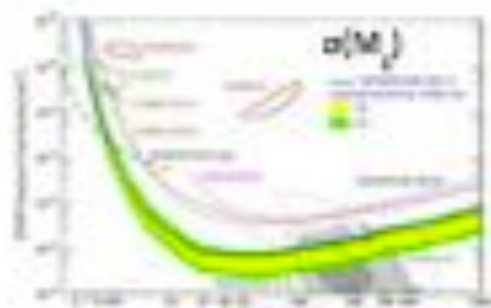


Event selection, remove bad events:
- noise
- S1/S2 not matching
Select single interaction events
Acceptances!

profile likelihood

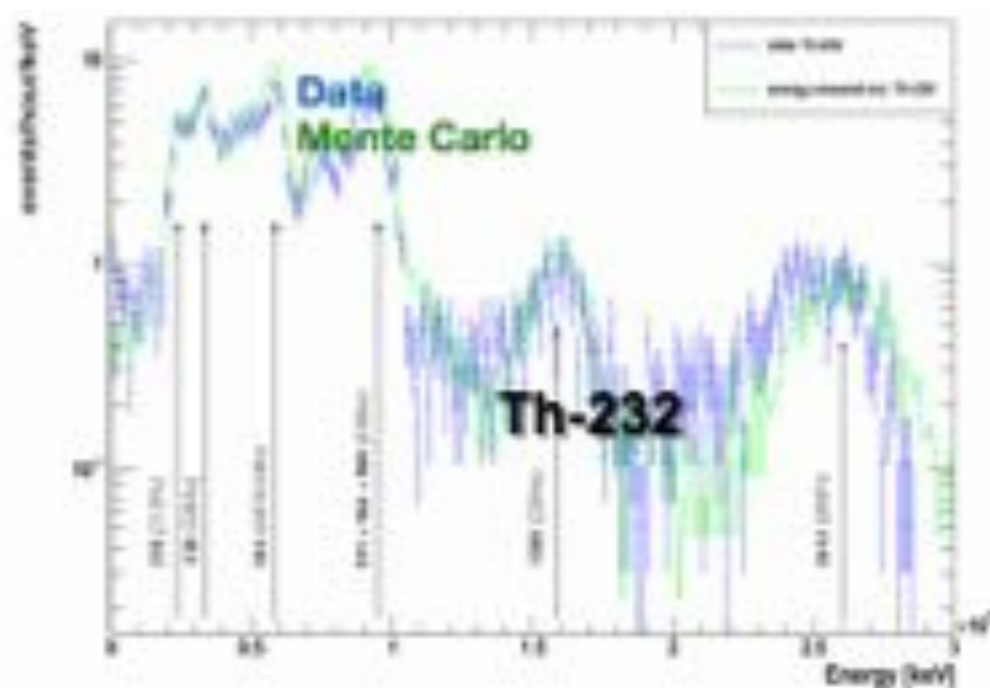
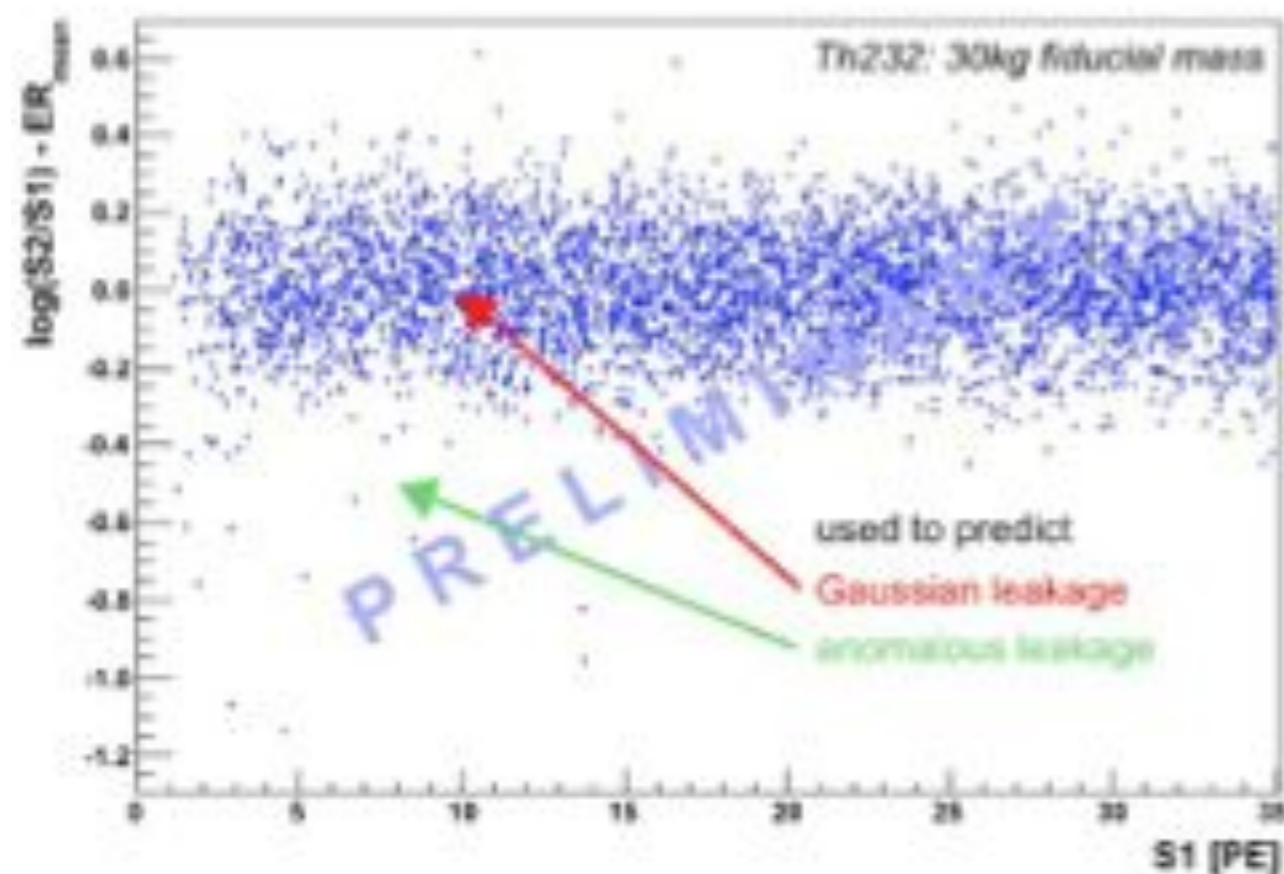


results



XENON100 gamma calibrations

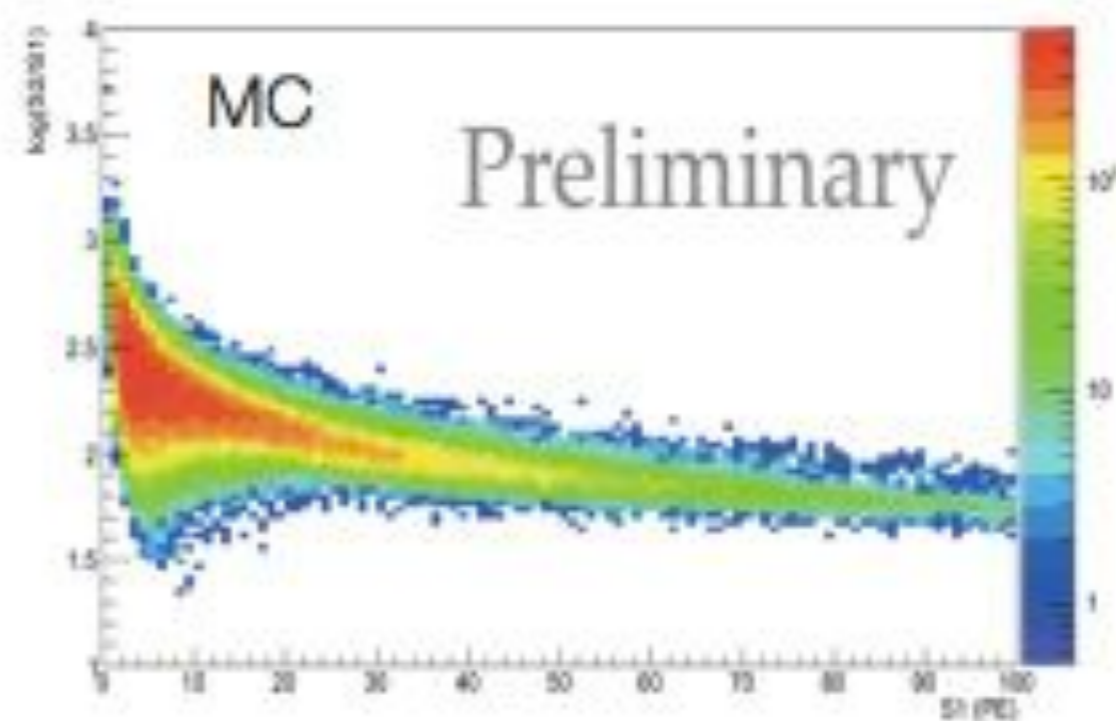
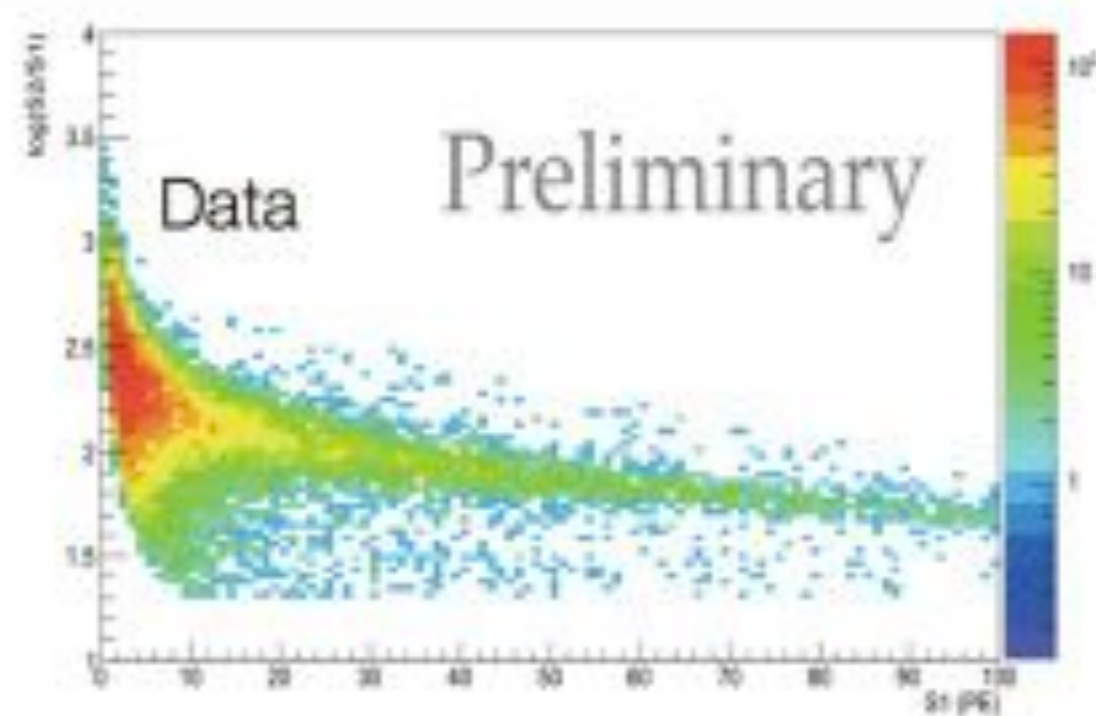
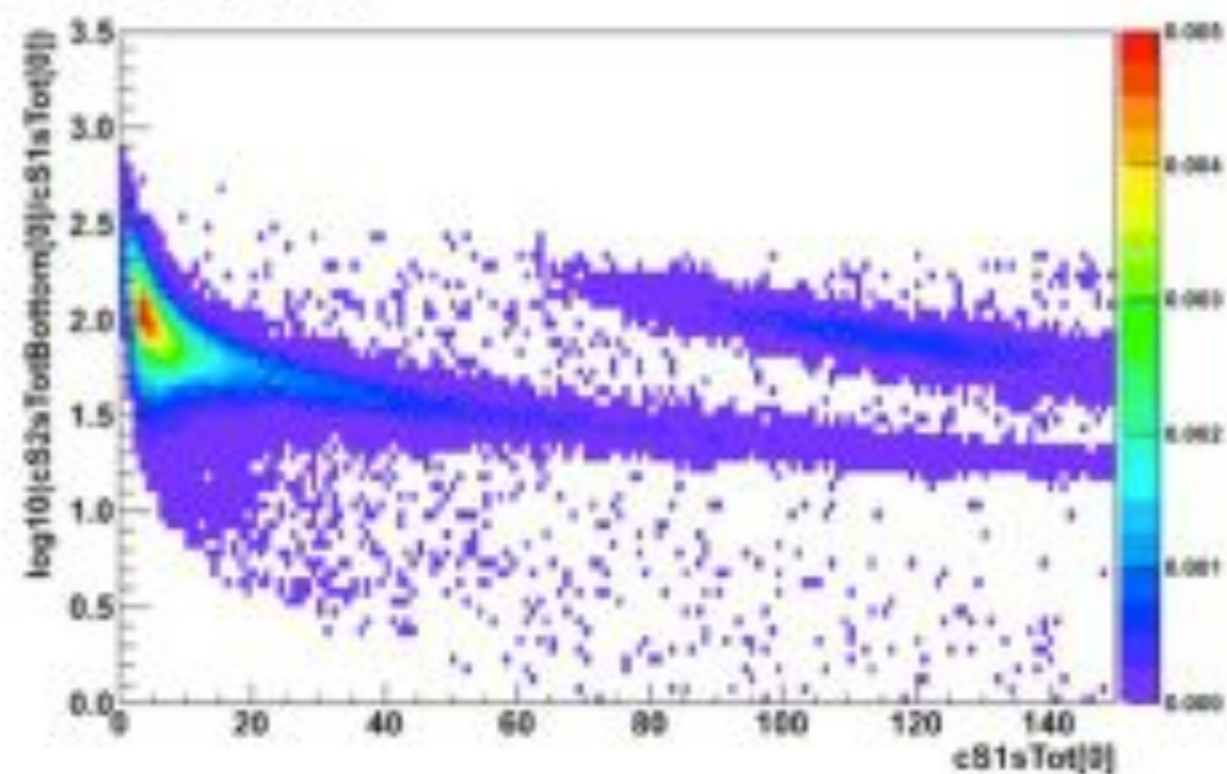
- ^{137}Cs data to monitor the charge & light yields
- ^{60}Co and ^{232}Th data used to map the electron recoil band and predict EM background (irradiate at three points around TPC)
- ^{232}Th data also used to understand spectrum up to high energies



XENON100 neutron calibration

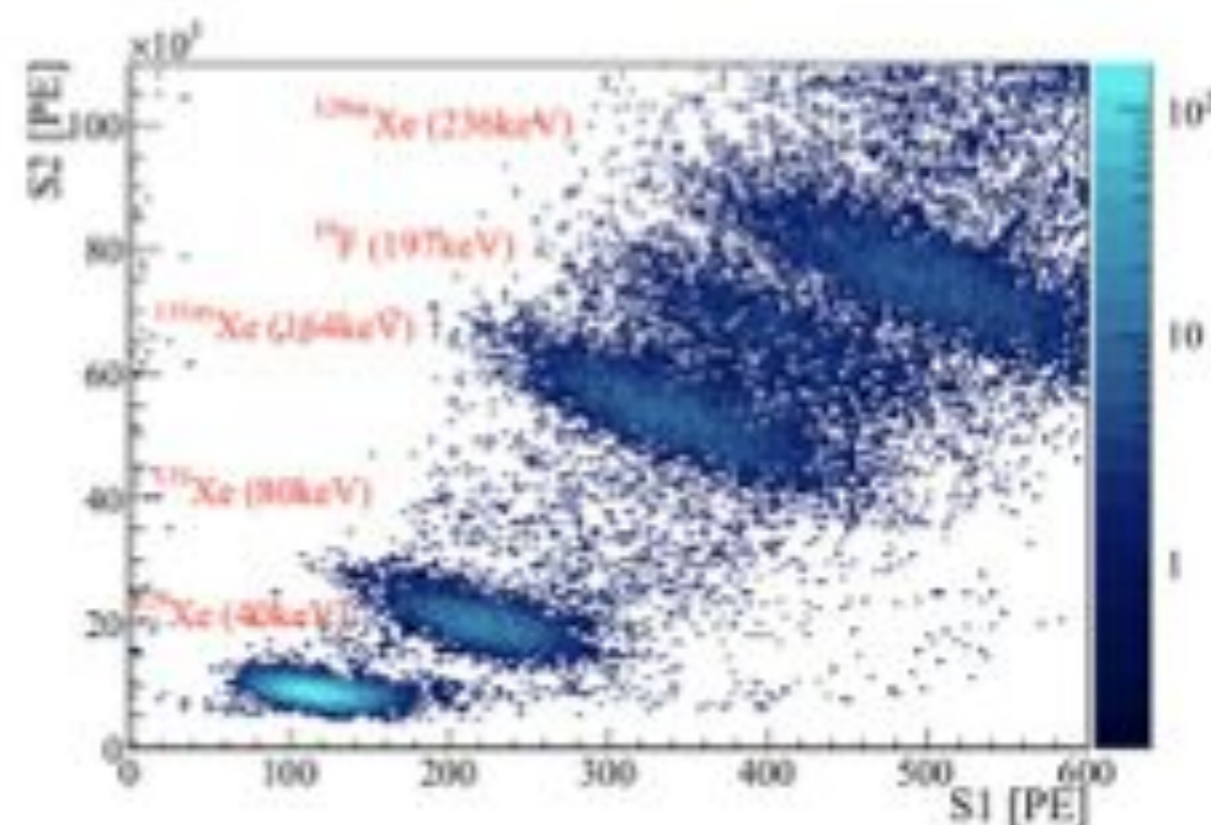
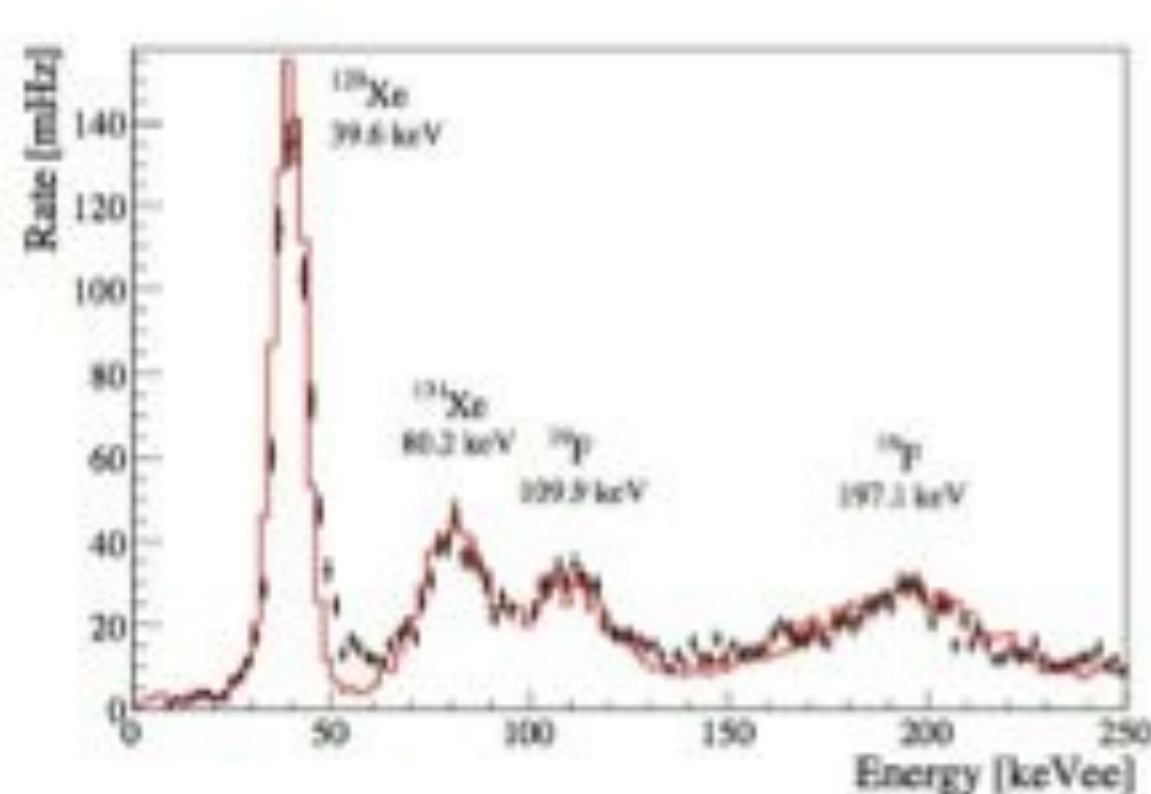
- Nuclear Recoil band calibration performed with a 220 n/s AmBe neutron source

AmBe Band (2012)



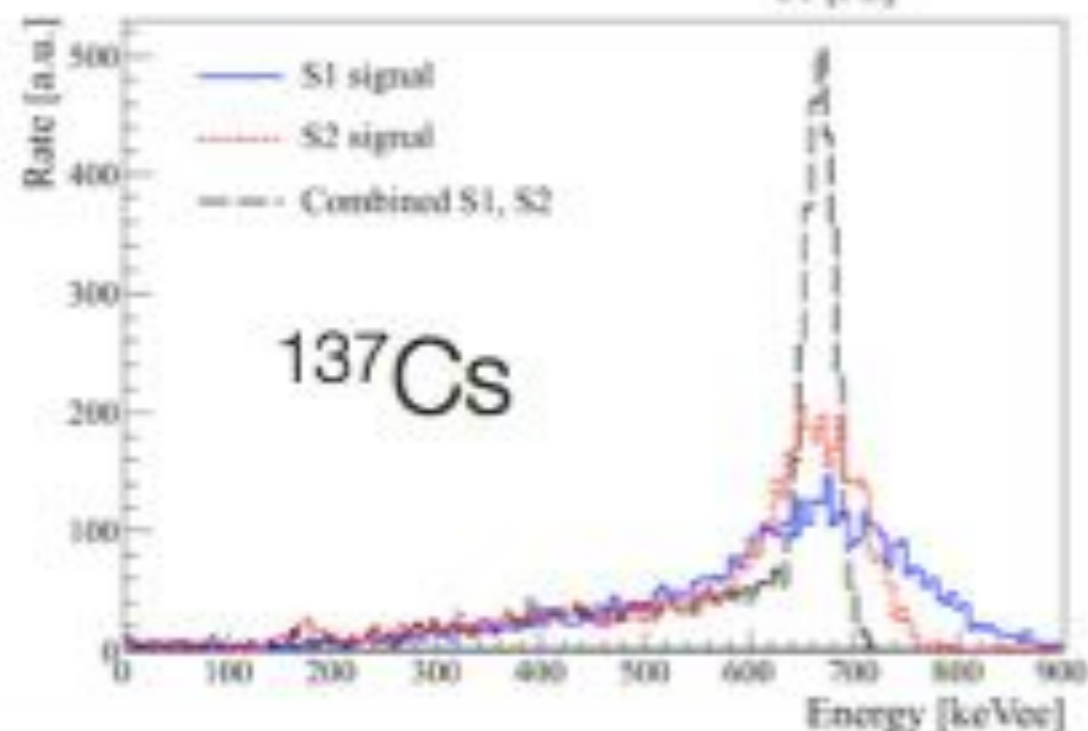
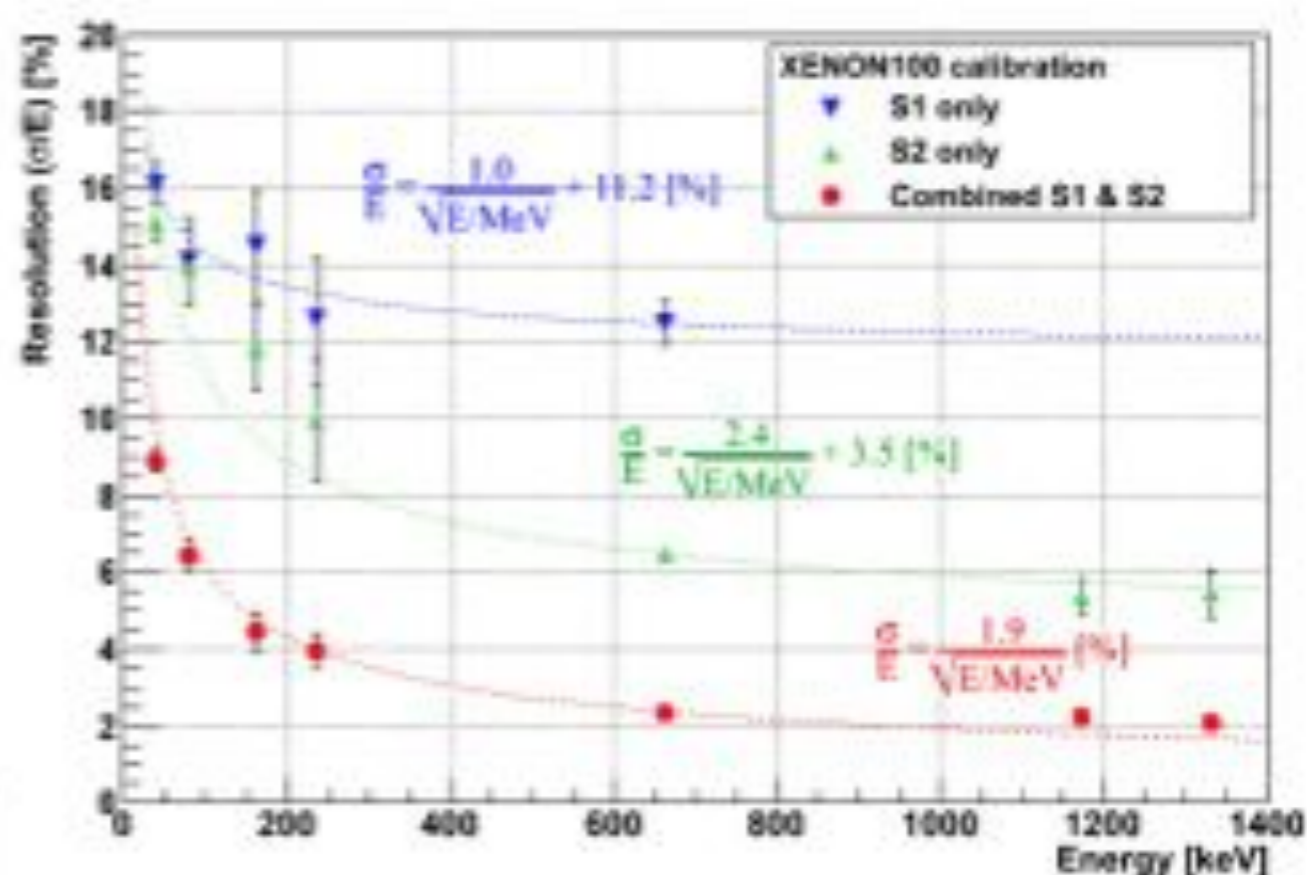
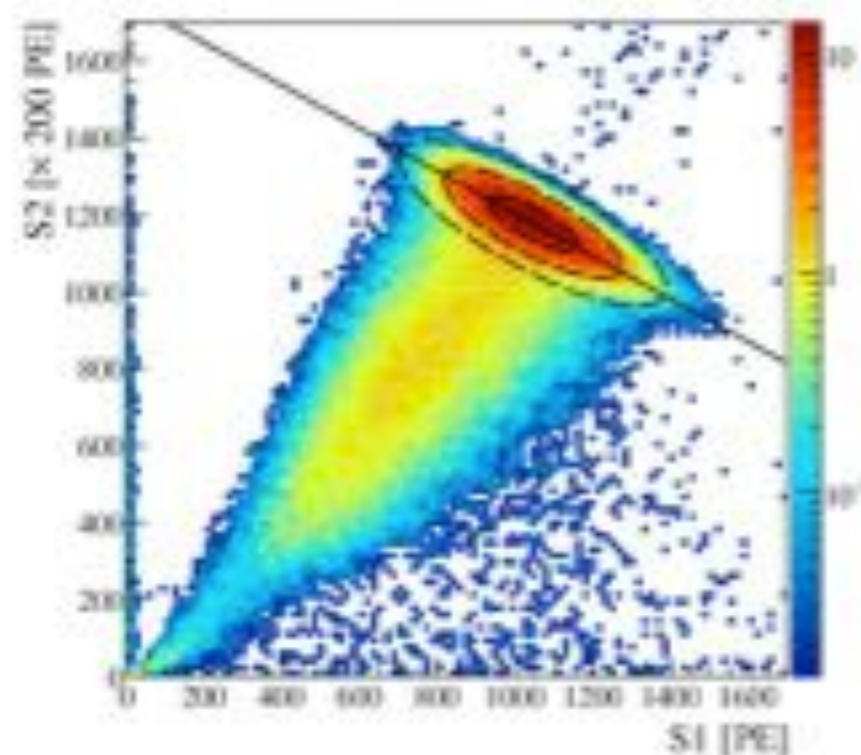
Gammas from neutron calibrations

- AmBe (~ MeV neutrons) data to map the nuclear recoil band, 220 n/s
- Inelastic n-scattering on Xe: $^{129,131}\text{Xe} + n \rightarrow ^{129,131}\text{Xe} + n + \gamma$ (40 keV, 80 keV)
- Inelastic n-scattering on F (in PTFE): $^{19}\text{F} + n \rightarrow ^{19}\text{F} + n + \gamma$ (110 keV, 197 keV)
- Also Xe activation lines: $^{129\text{m}}\text{Xe}$ (236 keV) and $^{131\text{m}}\text{Xe}$ (164 keV)



All gammas from the neutron irradiation of XENON100 are used to check/correct signal dependency with position and also to infer the LY at 122 keV

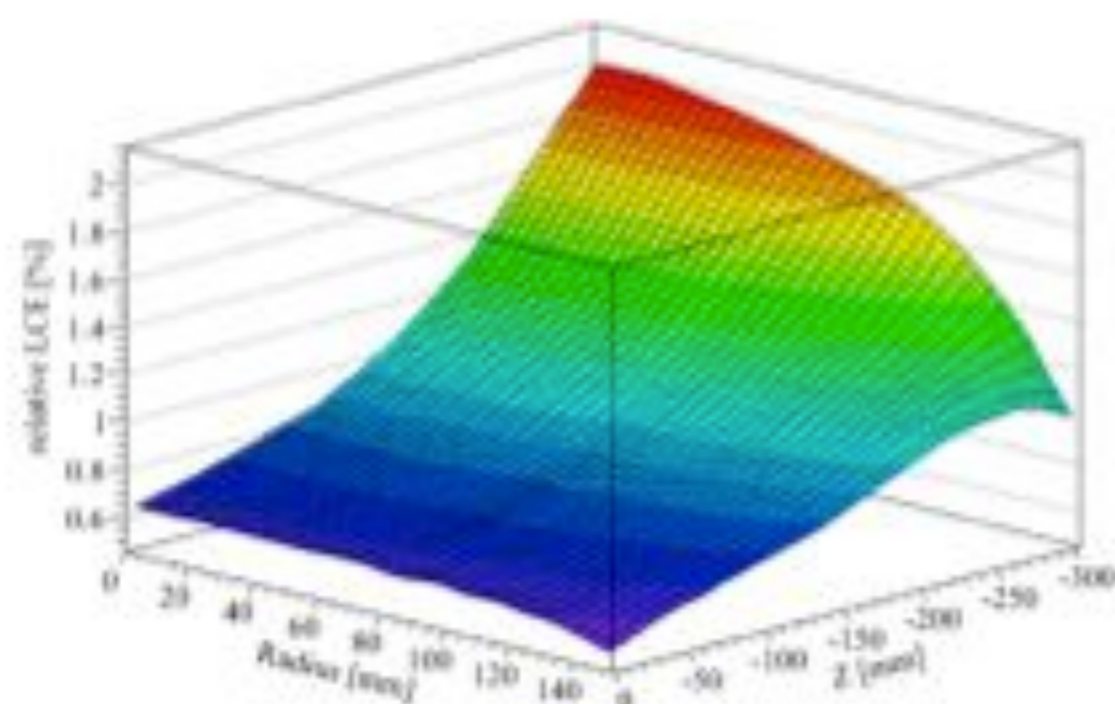
XENON100 energy resolution



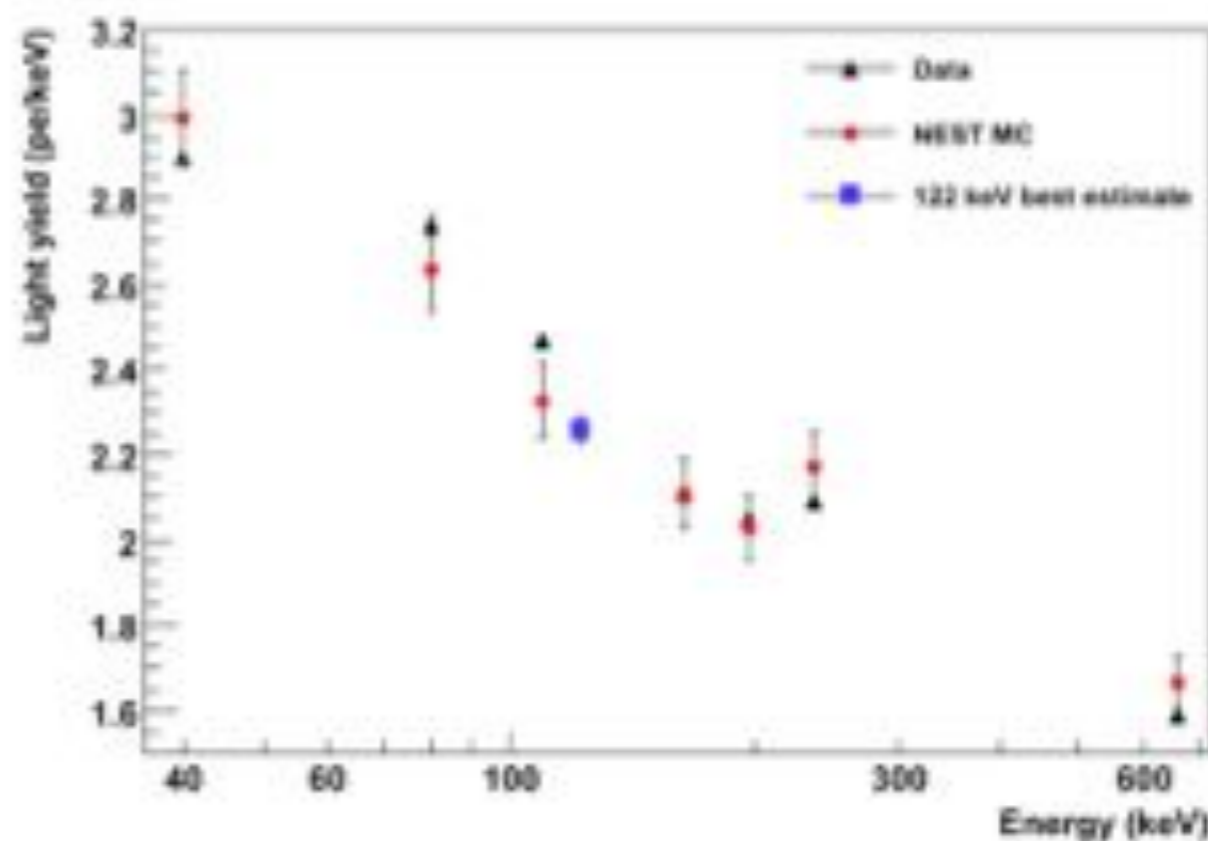
- Energy dependent energy resolution
- In S1, in S2 and in the "combined energy scale"
- Because of the anti-correlation of the S1 and S2 signals, the resolution is much improved when using both

S1 Signal Corrections

- S1 light collection depends on the event position in the TPC: a 3D map of the light collection efficiency (LCE) is inferred from irradiation with ^{137}Cs (662 keV) at different positions, from the 40 keV neutron inelastic scattering line, and the 164 keV line from n-activated $^{131\text{m}}\text{Xe}$ (all agree within 3%)
- Light yield at 122 keV is interpolated using NEST model and measurements at lower/higher energies with conservative 5% uncertainty. For Run10 the $\text{LY}_{122\text{keV}} = (2.28 \pm 0.04) \text{ PE/keV}$



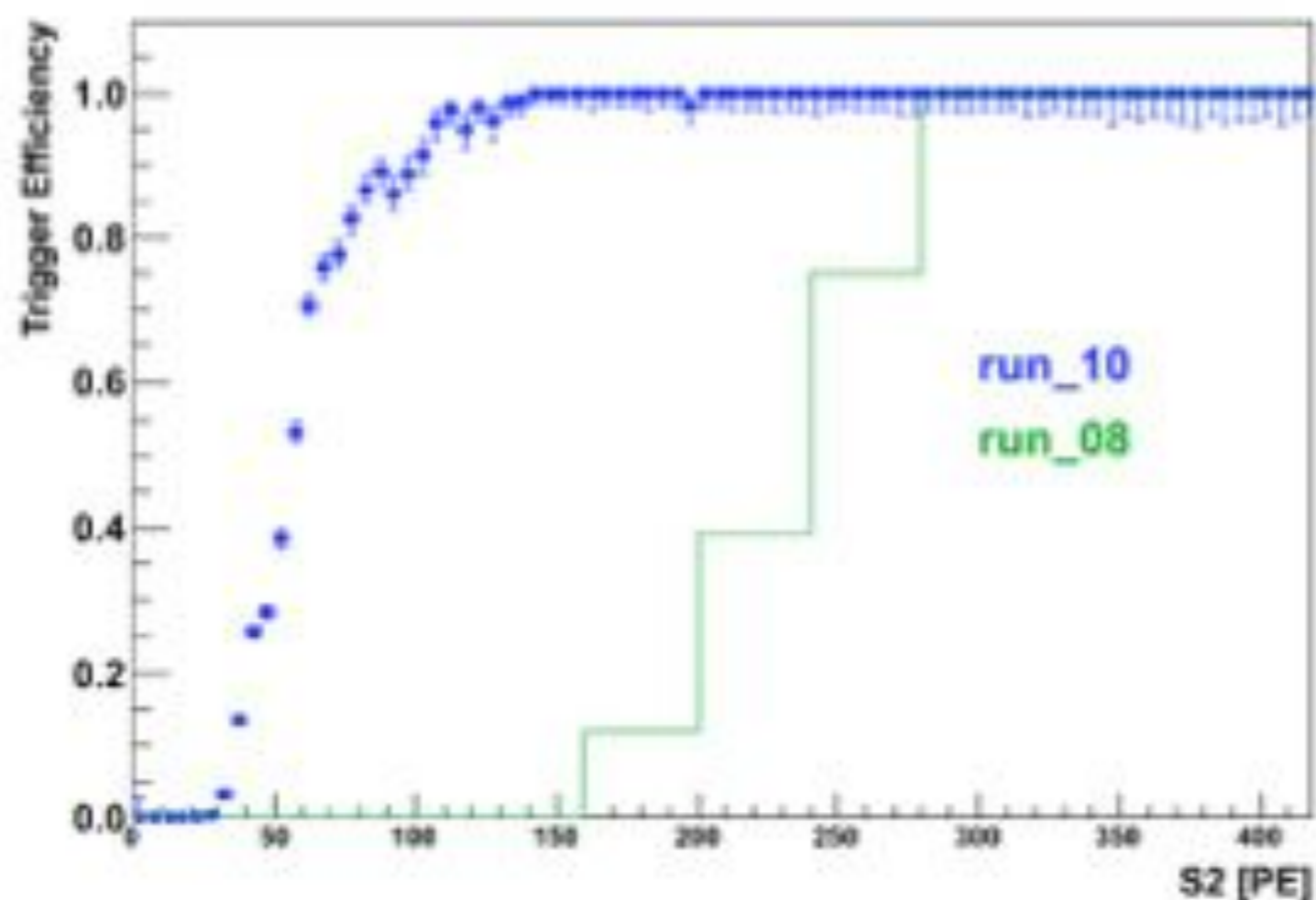
LCE correction map using the 40 keV line



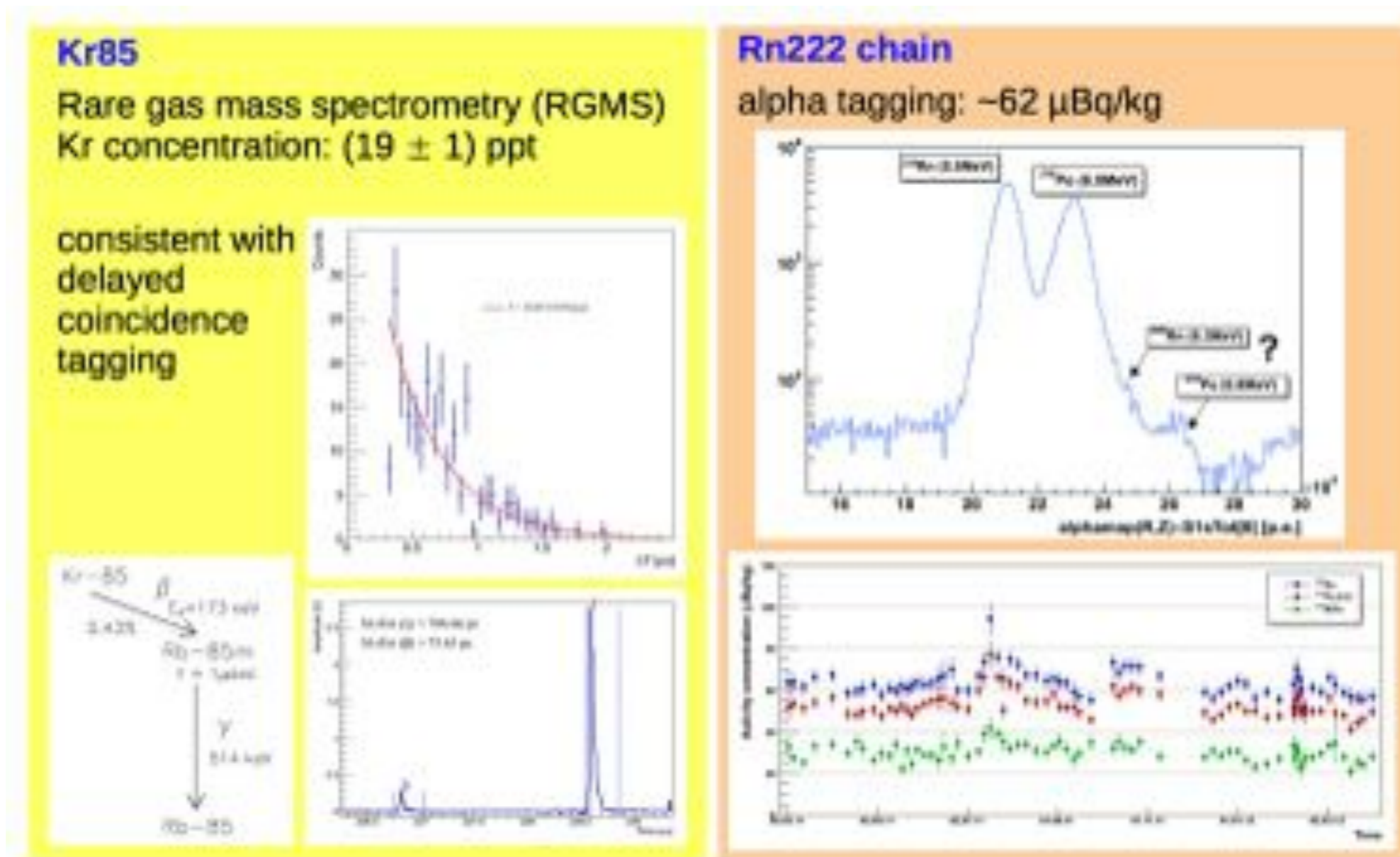
Light yield for different gamma lines

Improved S2 Trigger Efficiency

- 100% efficiency above S2= 150 photoelectrons
- ability to trigger on very low energy events (~10 electrons!)



Intrinsic backgrounds

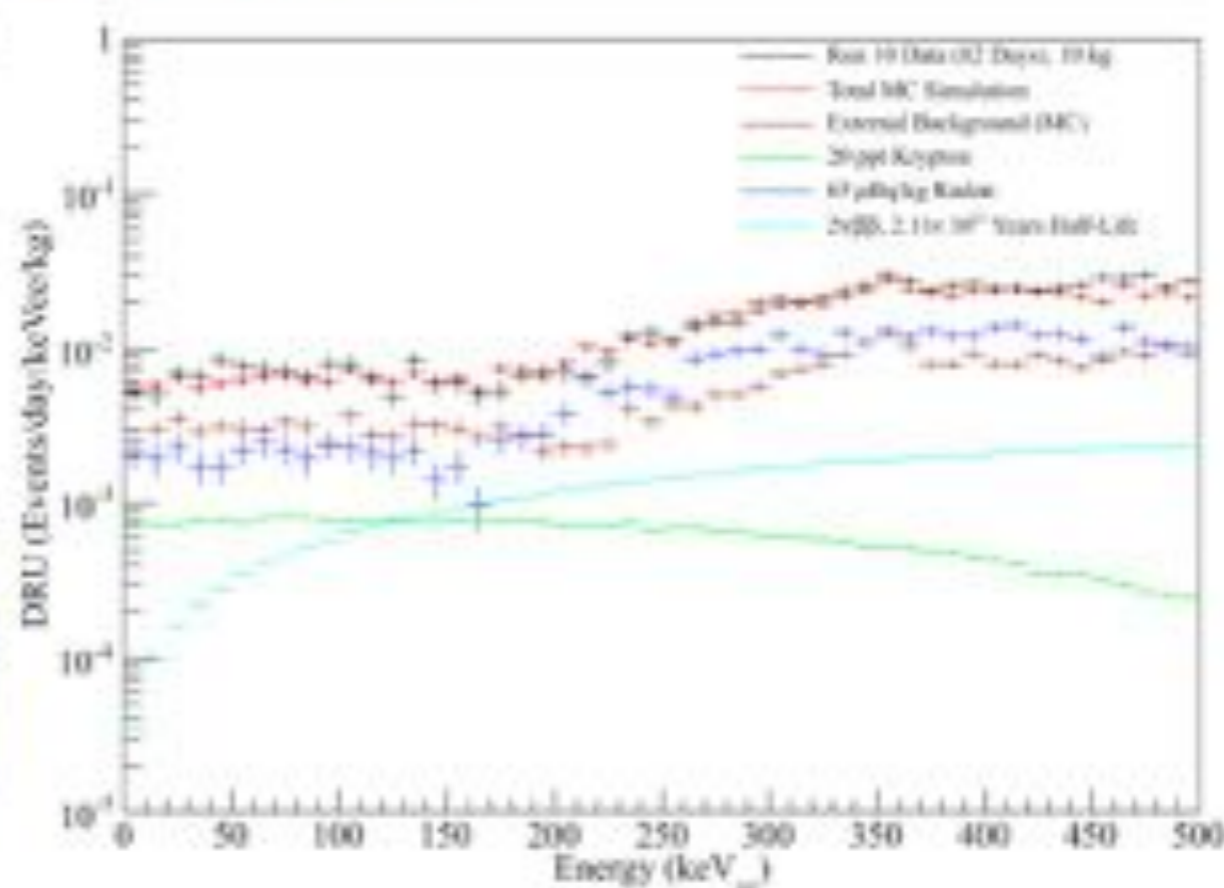
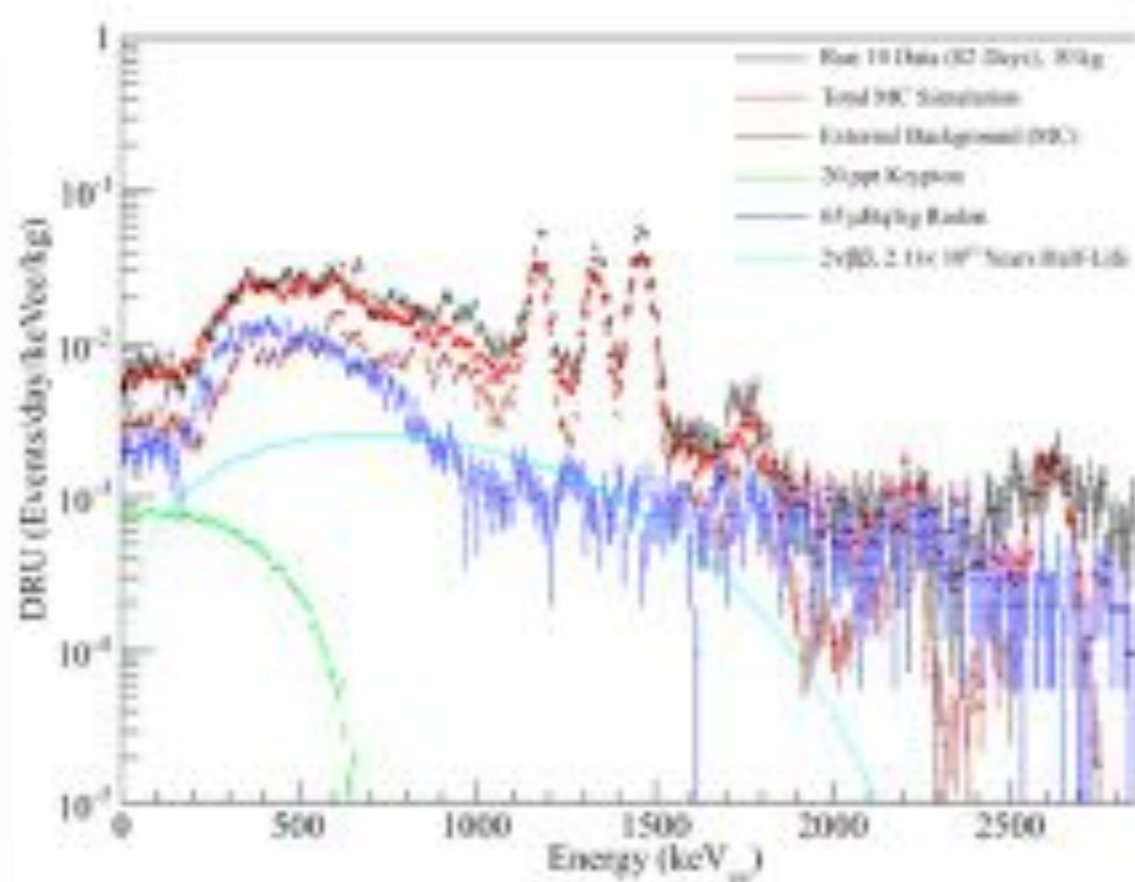


LXeTPCs easily identify surface backgrounds, alphas and delayed coincidences with 3D vertex and energy reconstruction

Measured Background Level in Run10

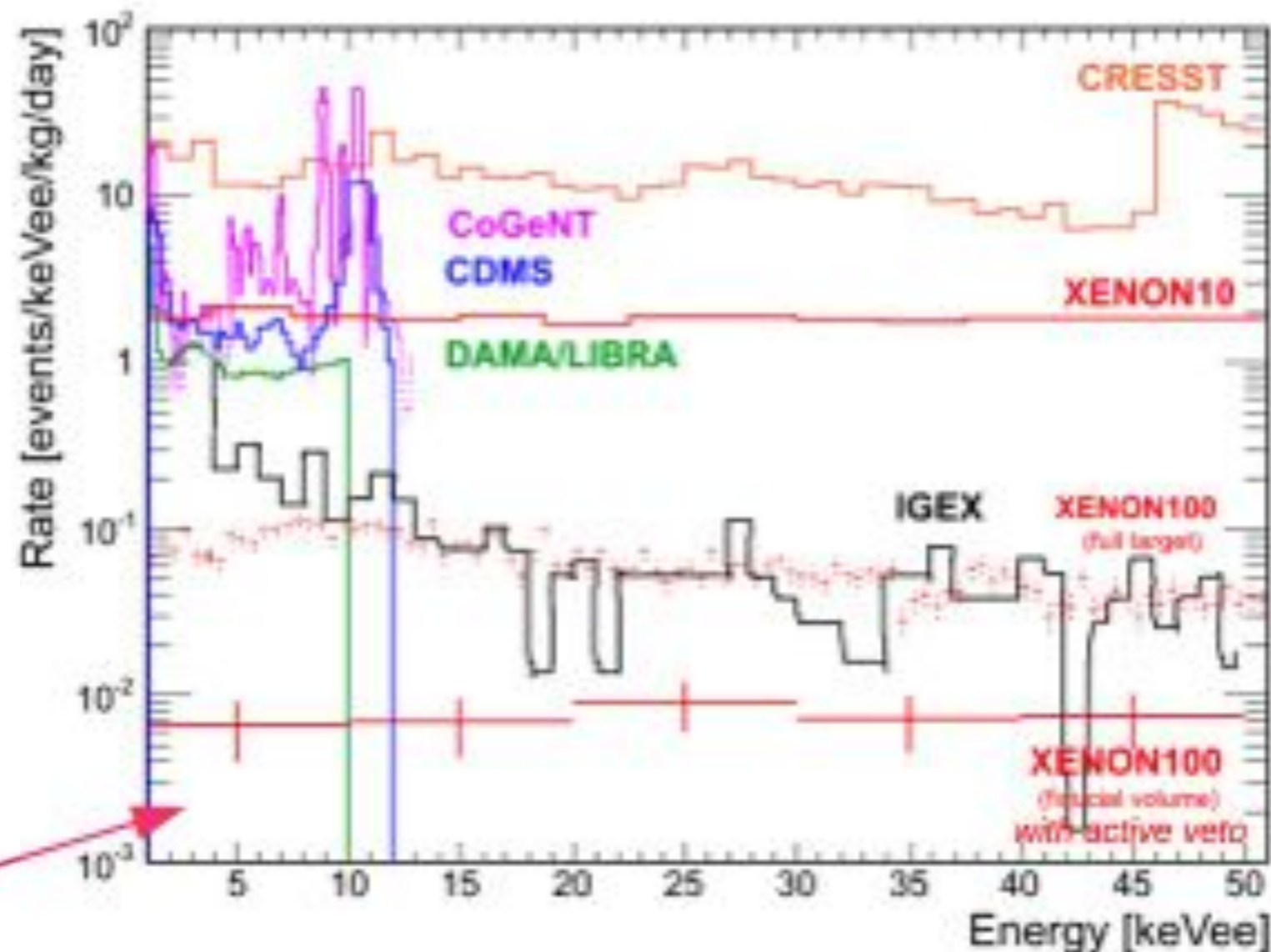
- Reached background level before S2/S1-discrimination: 5.3×10^{-3} events/(kg day keV)
- Same level as in 1st XENON100 results (E. Aprile et al., Phys. Rev. Lett. **105**, 131302, 2010)
- see also PRD 83, 082001 (2011)

Before applying LXe veto cut



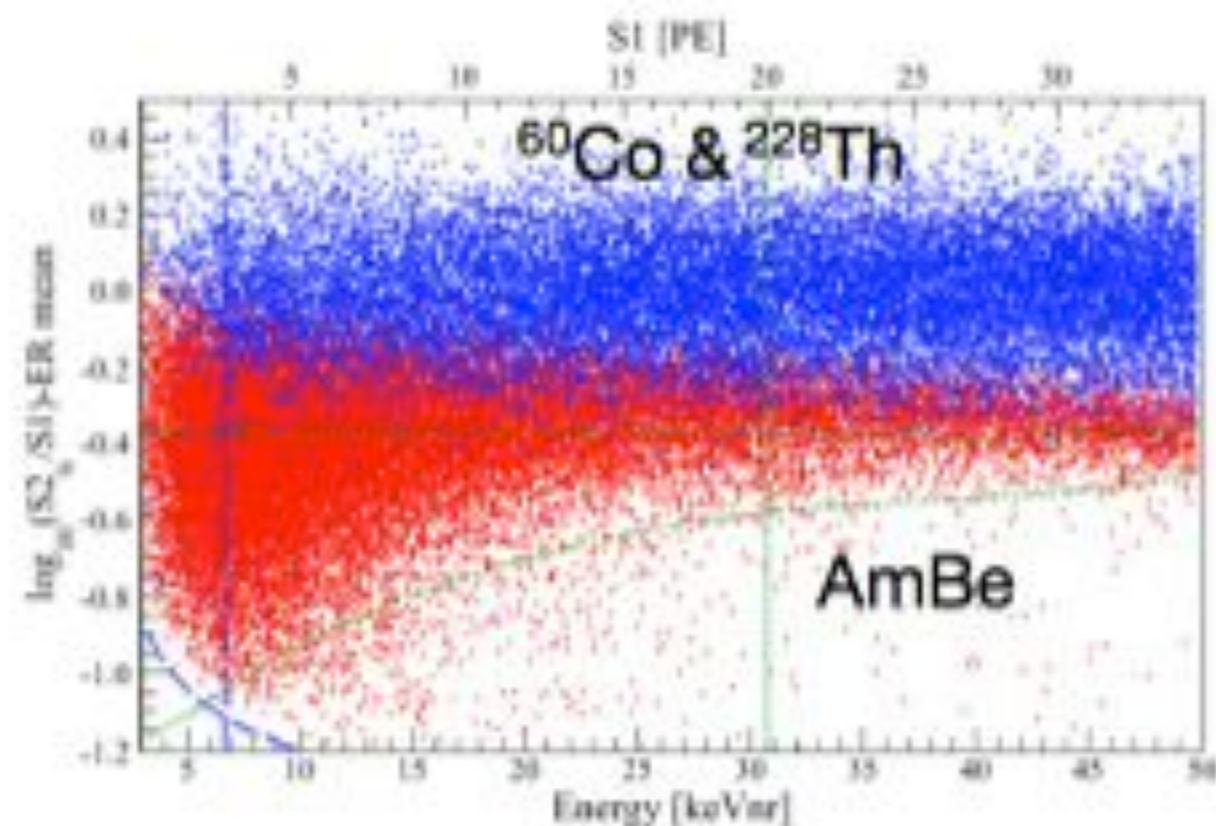
Measured Background in good agreement with MC prediction.

At low energies: Lowest background ever achieved in a Dark Matter Experiment!

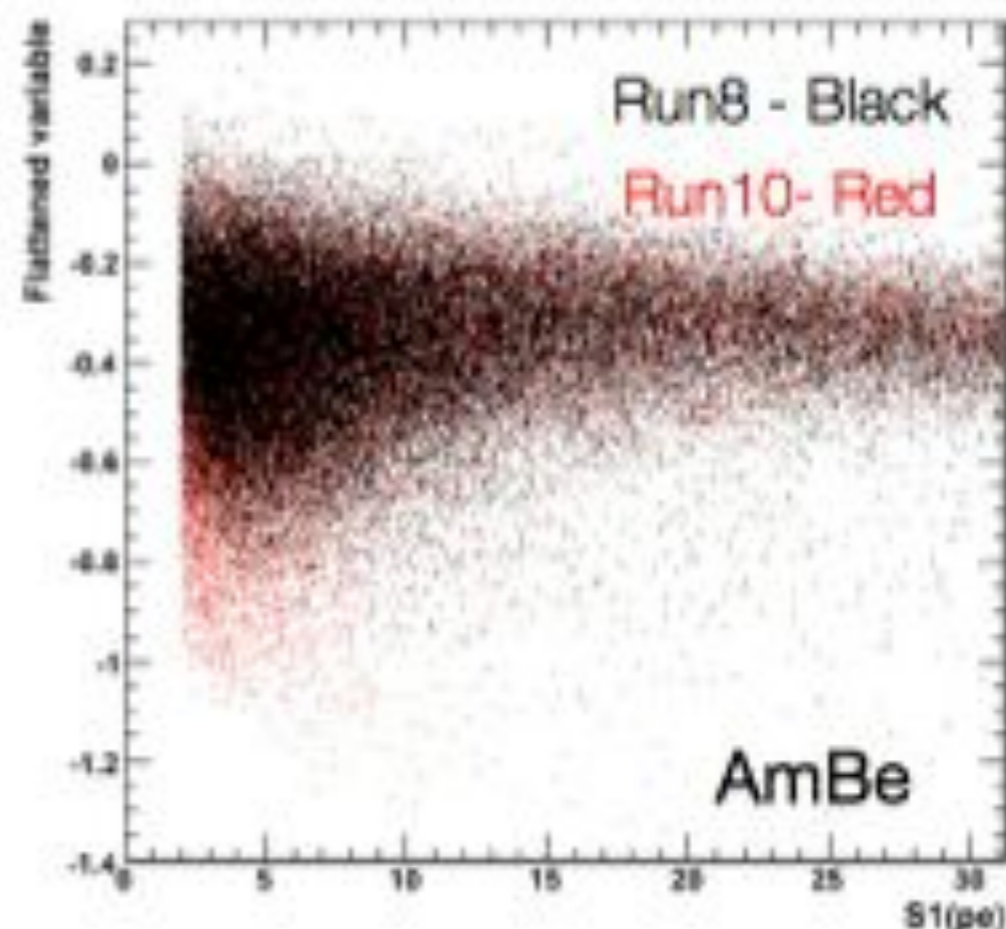


Xenon keVee-Scale not precisely known below 9 keVee

Improved Statistics of ER & NR Calibration Data



Gamma and neutron calibration data

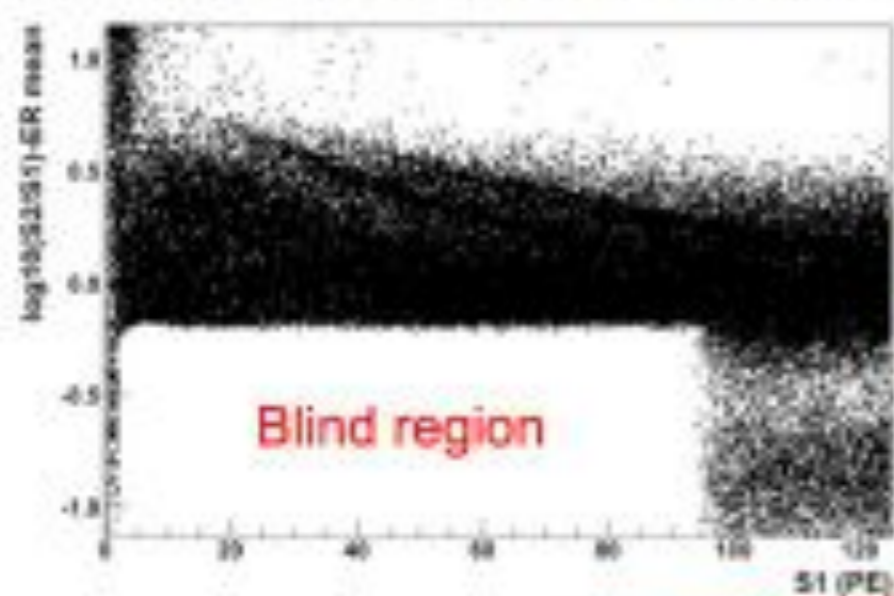


Lower Run10 S2 threshold visible

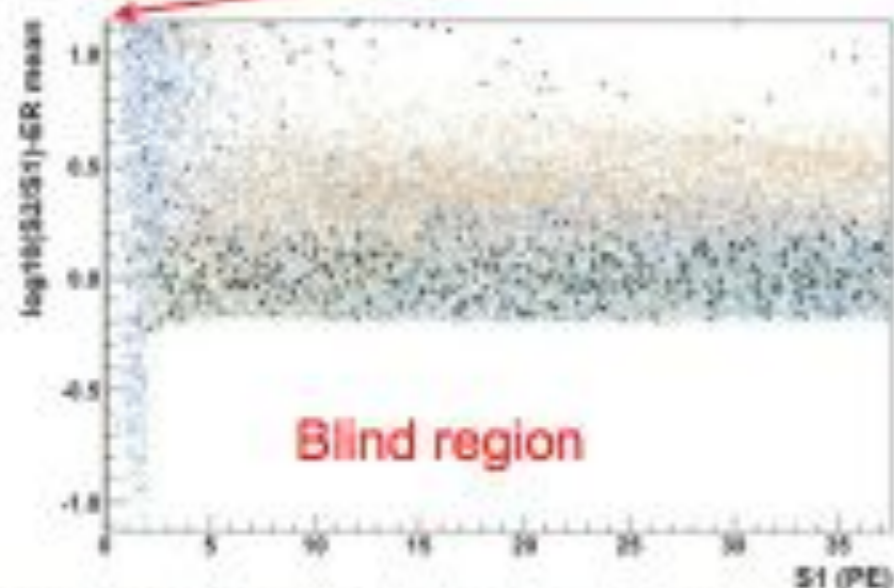
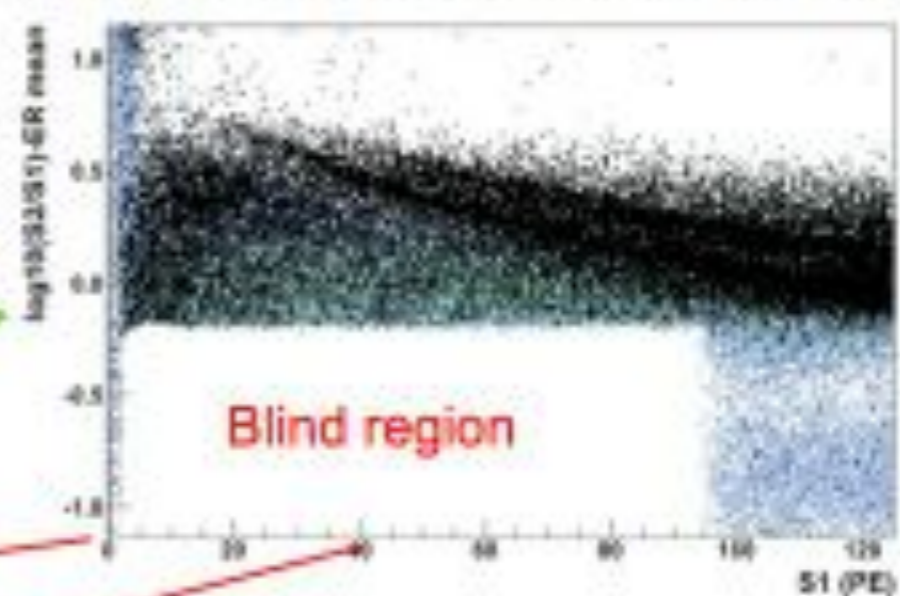
Analysis sequence for the 225 live days of data

(Different colors represent the events removed with the successive cuts)

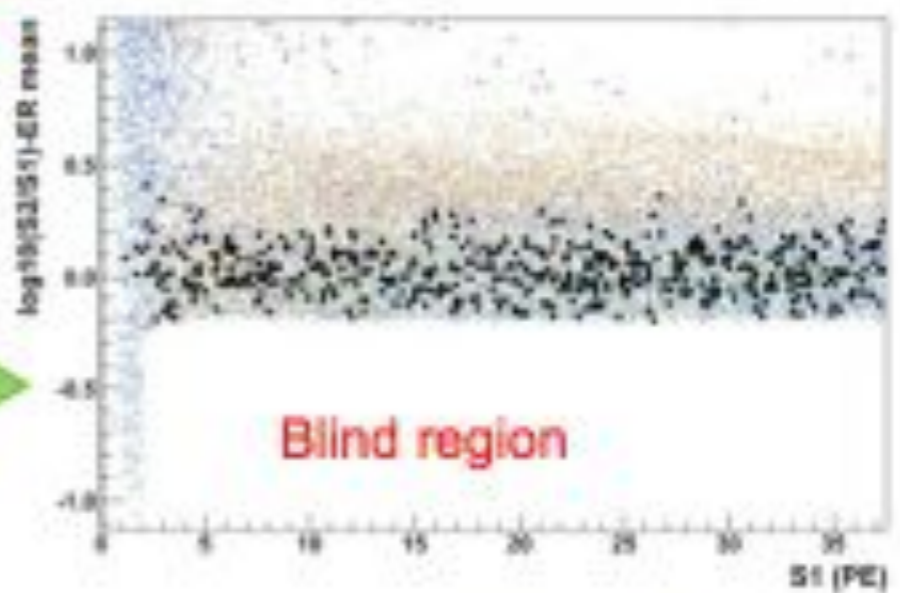
(1) Start from all non-blind data in 48kg FV



(2) Apply basic quality cuts and single scatter

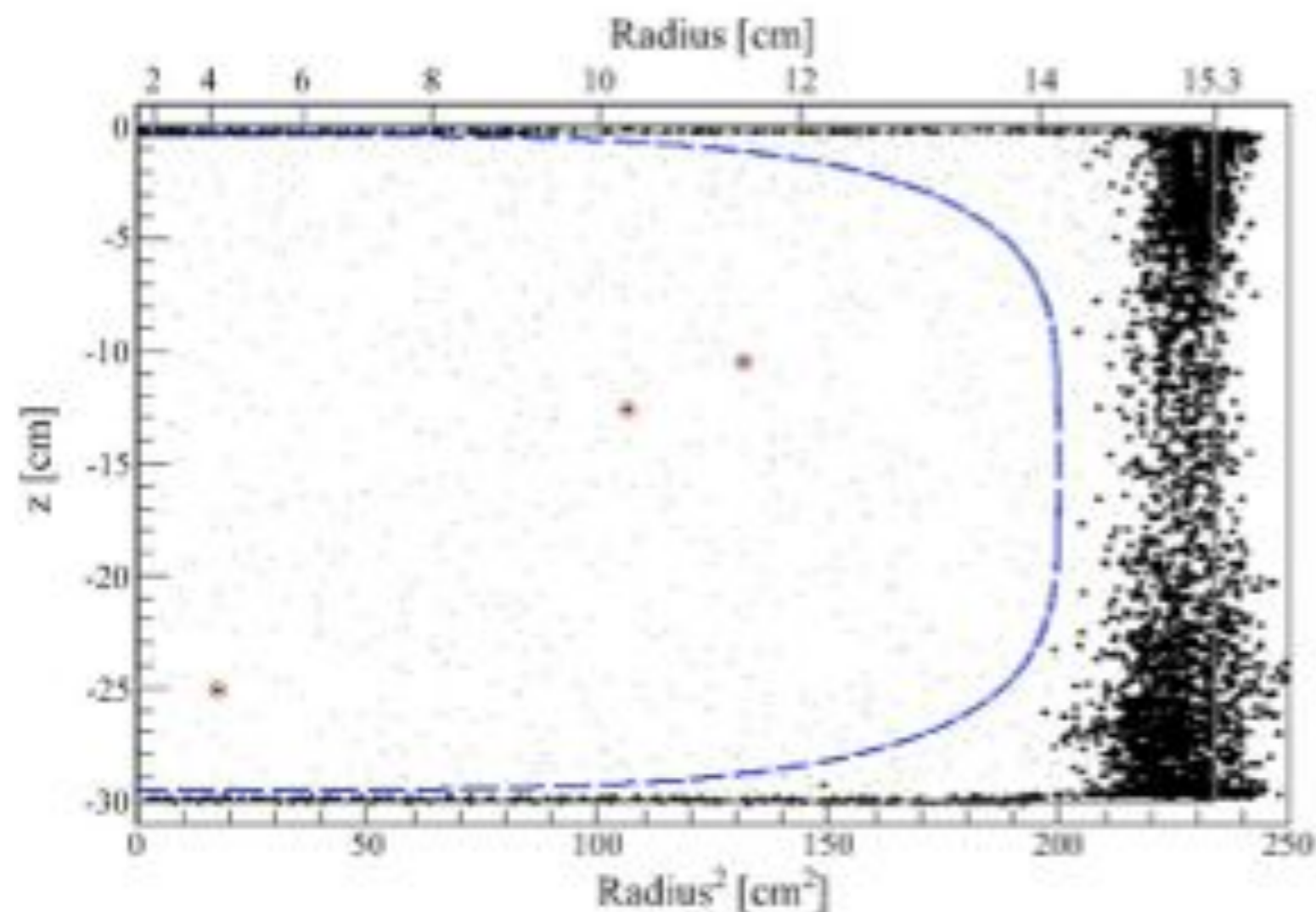


(3) Set low energy threshold, restrict to low energies and apply FV cut



(4) Add consistency cuts for the remaining events

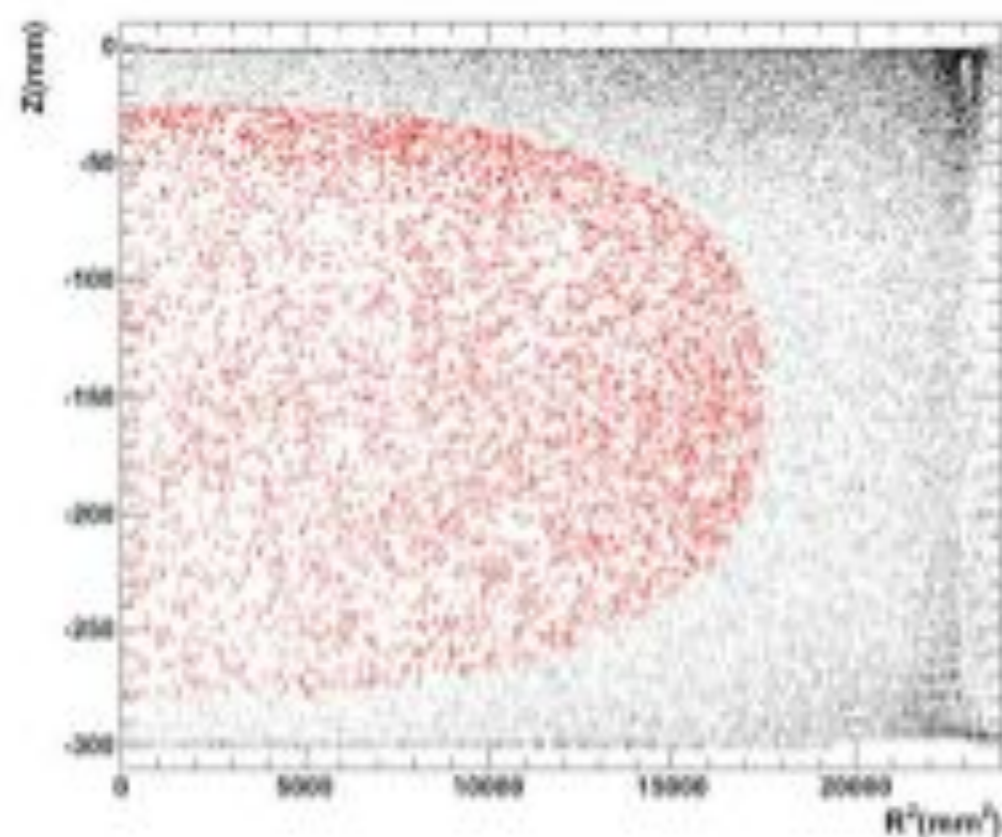
Volume Fiducialization: power of a TPC



Background from published data (PRL 107)

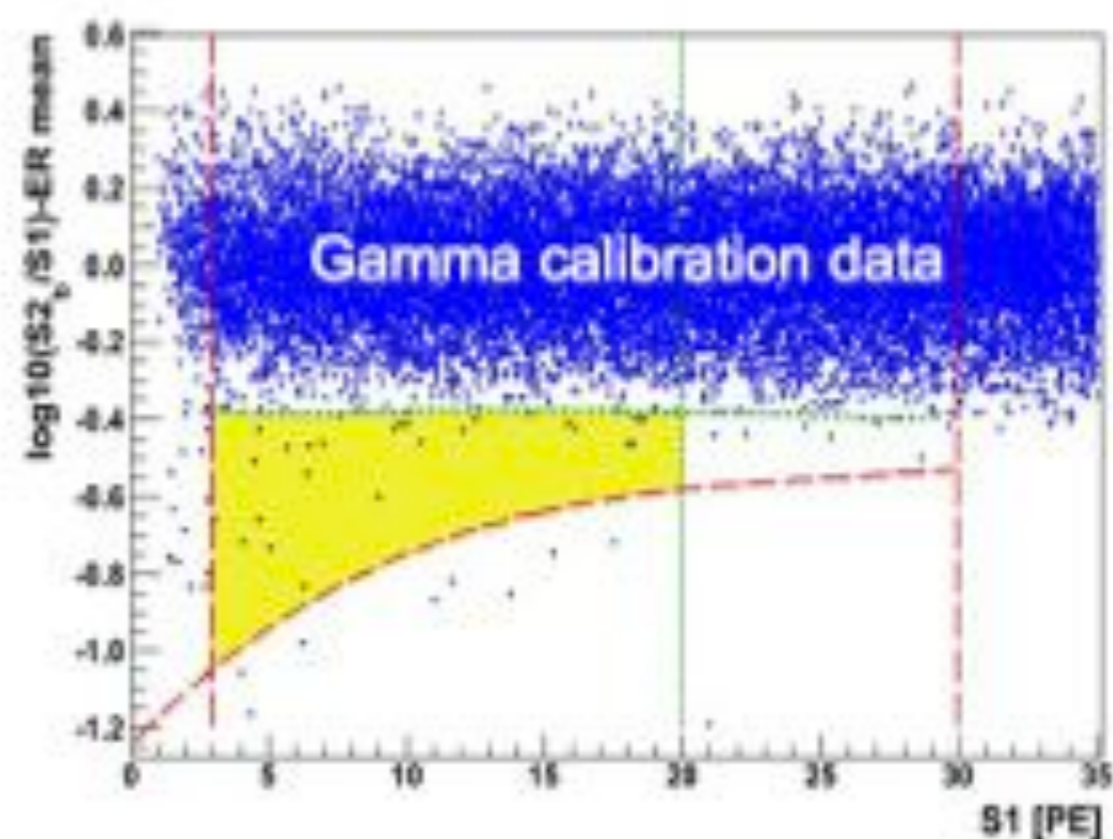
- 3D event imaging allows to select only central volume with lowest background exploiting LXe self-shielding
- Gammas from detector components and external sources stopped at edges
- Remaining background in fiducialized volume dominated by internal sources like ^{85}Kr and ^{222}Rn in LXe

Optimization of the fiducial volume and signal region

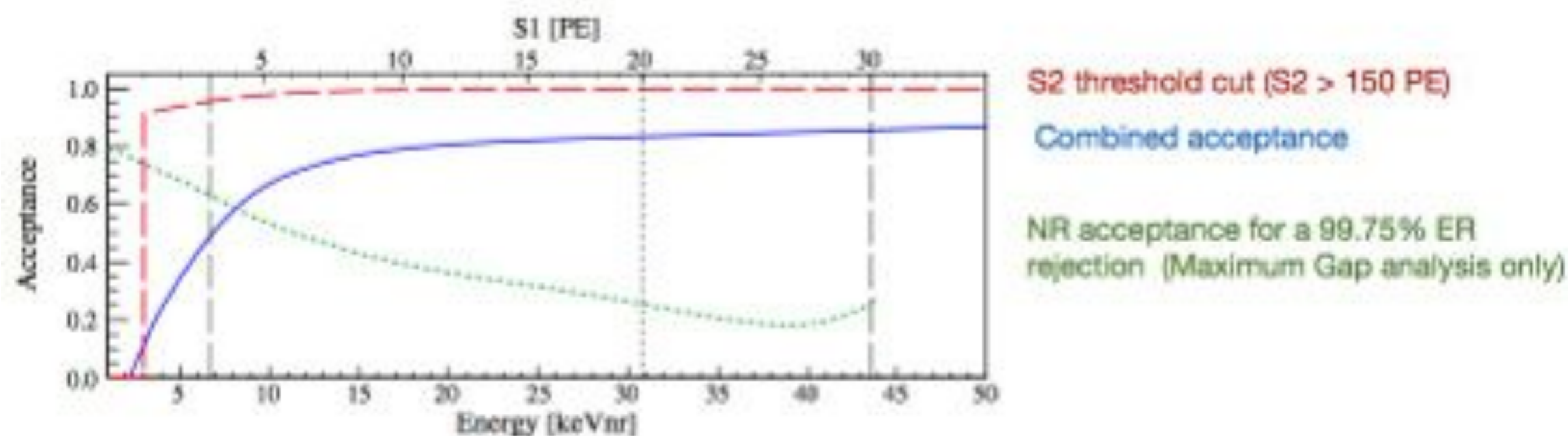


- The fiducial volume and signal region are simultaneously adjusted to maximize sensitivity
- Given the lower beta background in this run, we choose a smaller FV (34 kg) to profit from LXe self-shielding

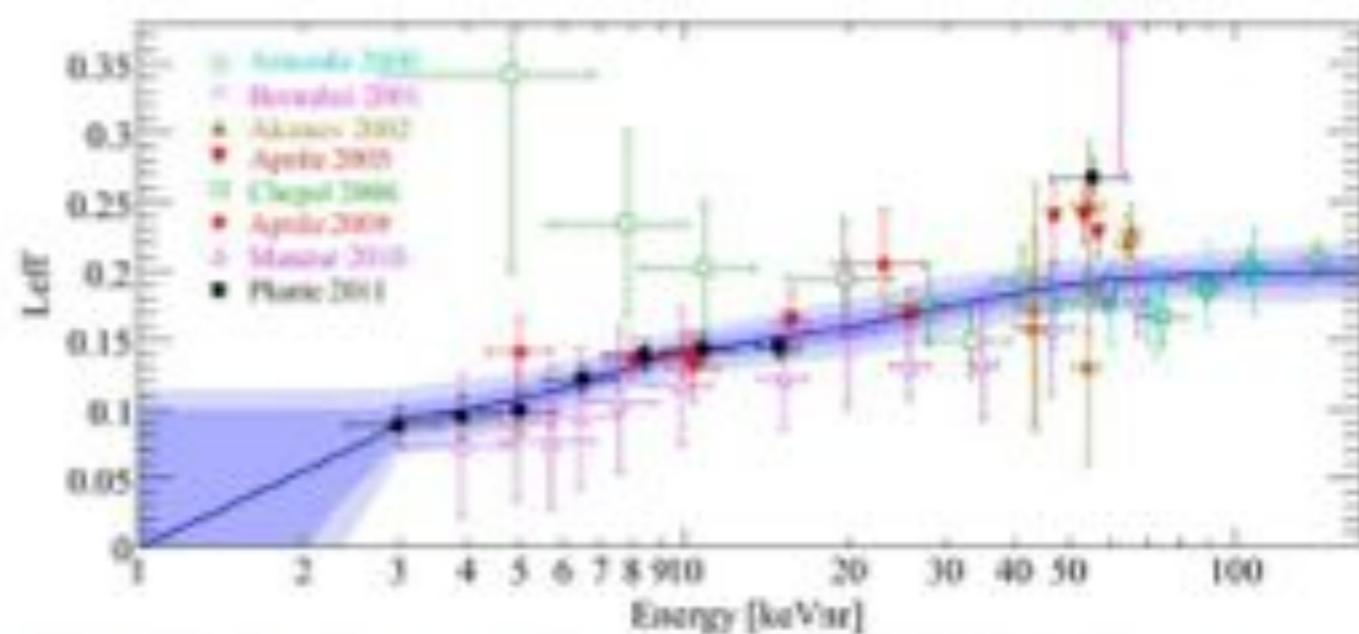
- The signal region is chosen below the 99.75% constant rejection line for ER
- The signal region for the Maximum-Gap based analysis is set between 3 and 20 PE



Cuts acceptance and L_{eff} parameterization

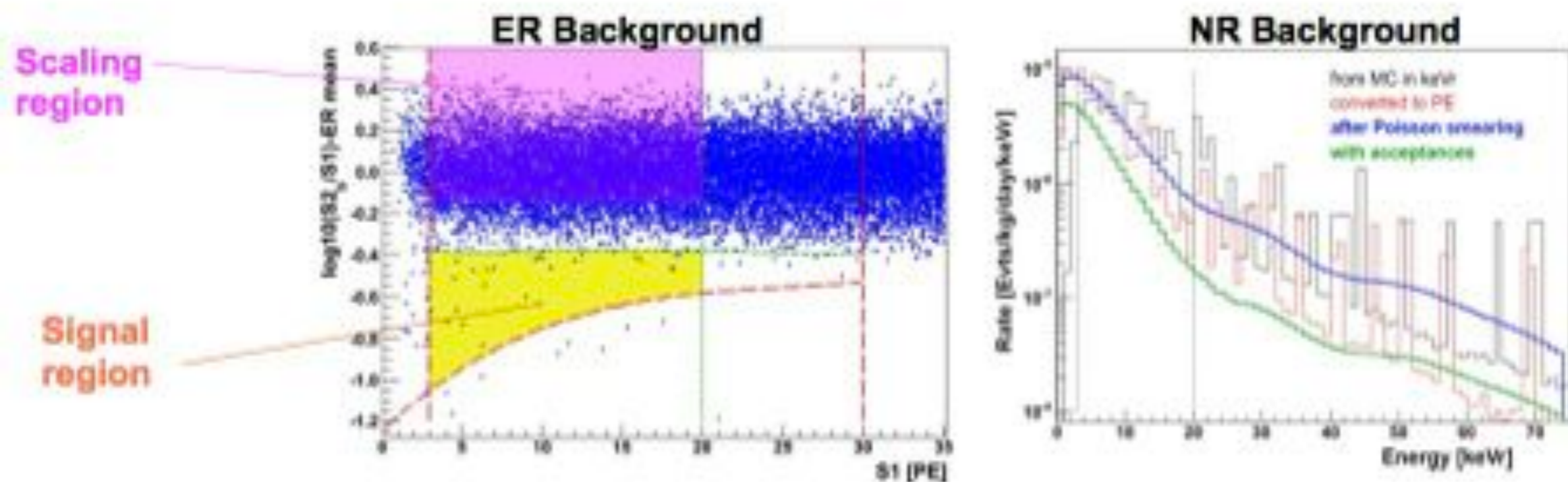


$$E_{nr} = \frac{S1}{L_{eff} \cdot L_y}$$



mean (solid) and 1- 2-sigma uncertainties (blue bands) of L_{eff} direct measurements

Background expectation



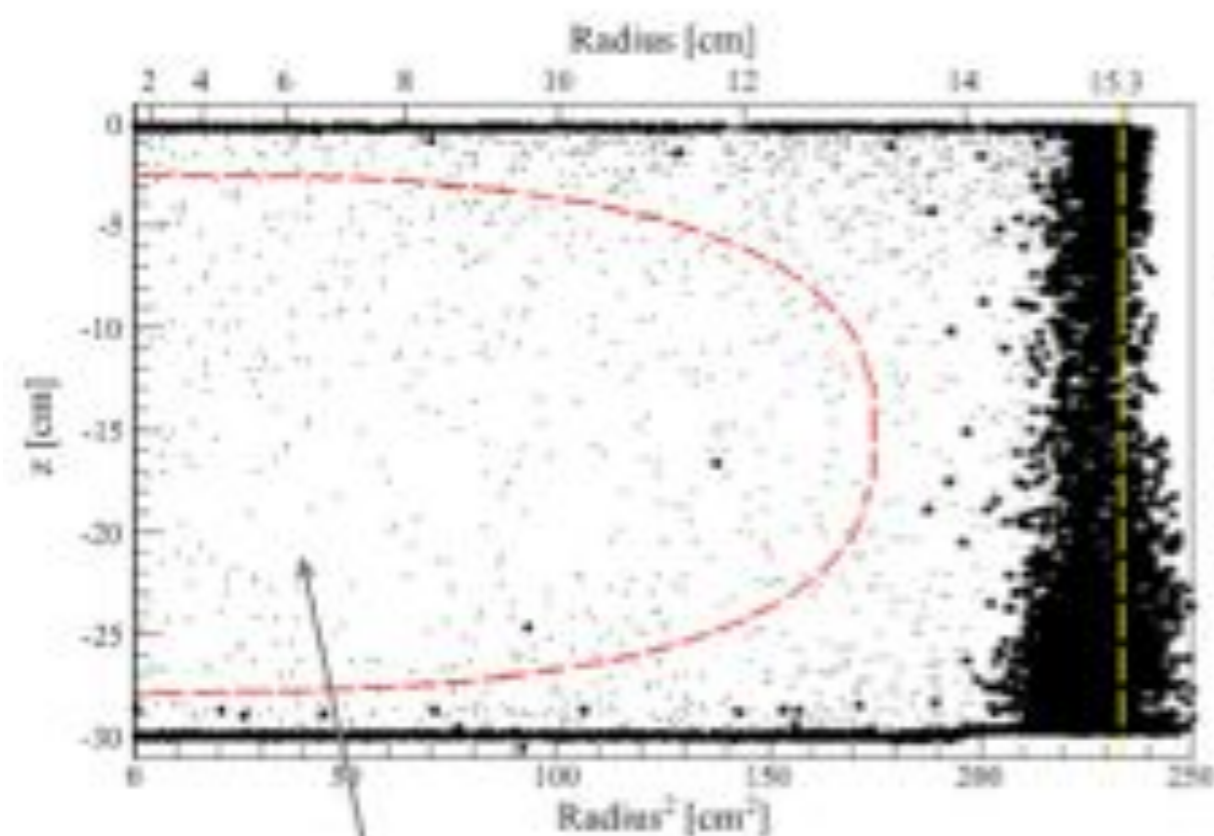
- The background expectation is computed from the calibration data
- The number of events in the signal region from ER calibration data is counted
- That number is scaled to the number of events in the non-blinded region
- An additional contribution from neutrons from the materials is added to the final number and scaled to the total exposure
- Background expectation: 1.0 ± 0.2 events (0.79 ± 0.16 from gammas, $0.17+0.12-0.07$ from neutrons)



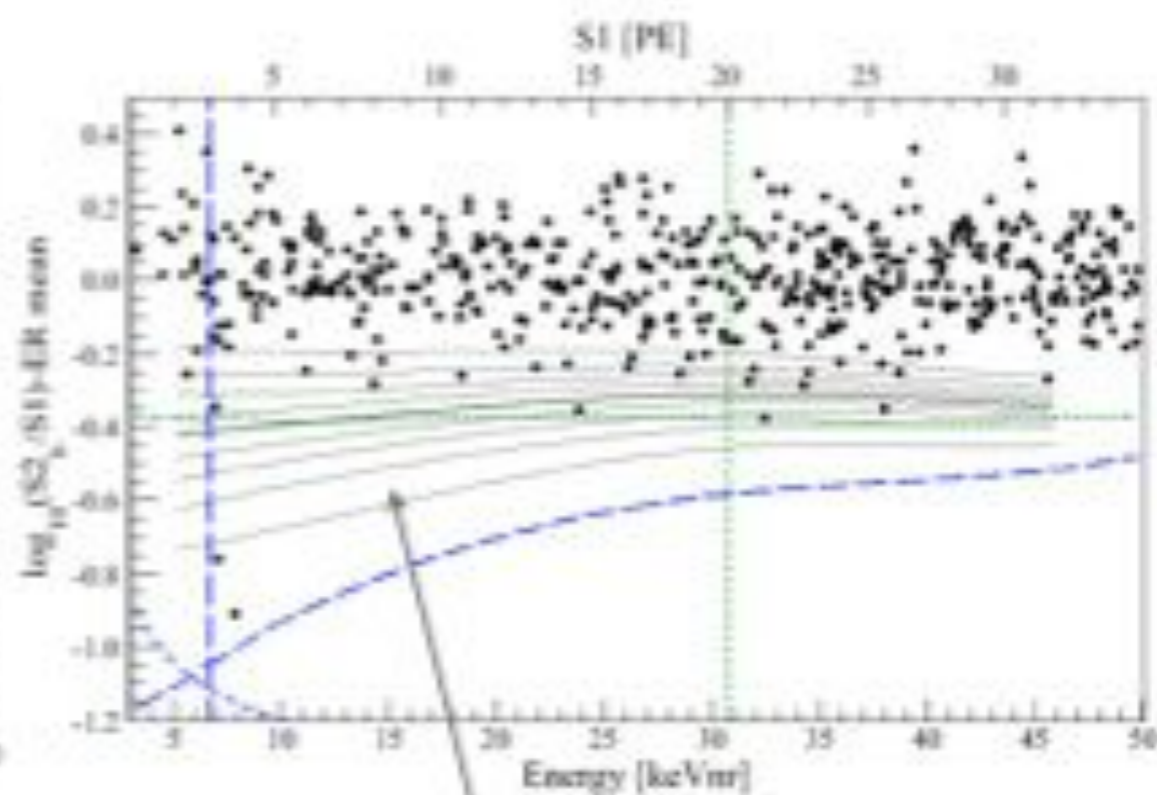
And the result....

Unblinding: Distribution of events in the TPC

Exposure: 225 days x 34 kg fiducial mass



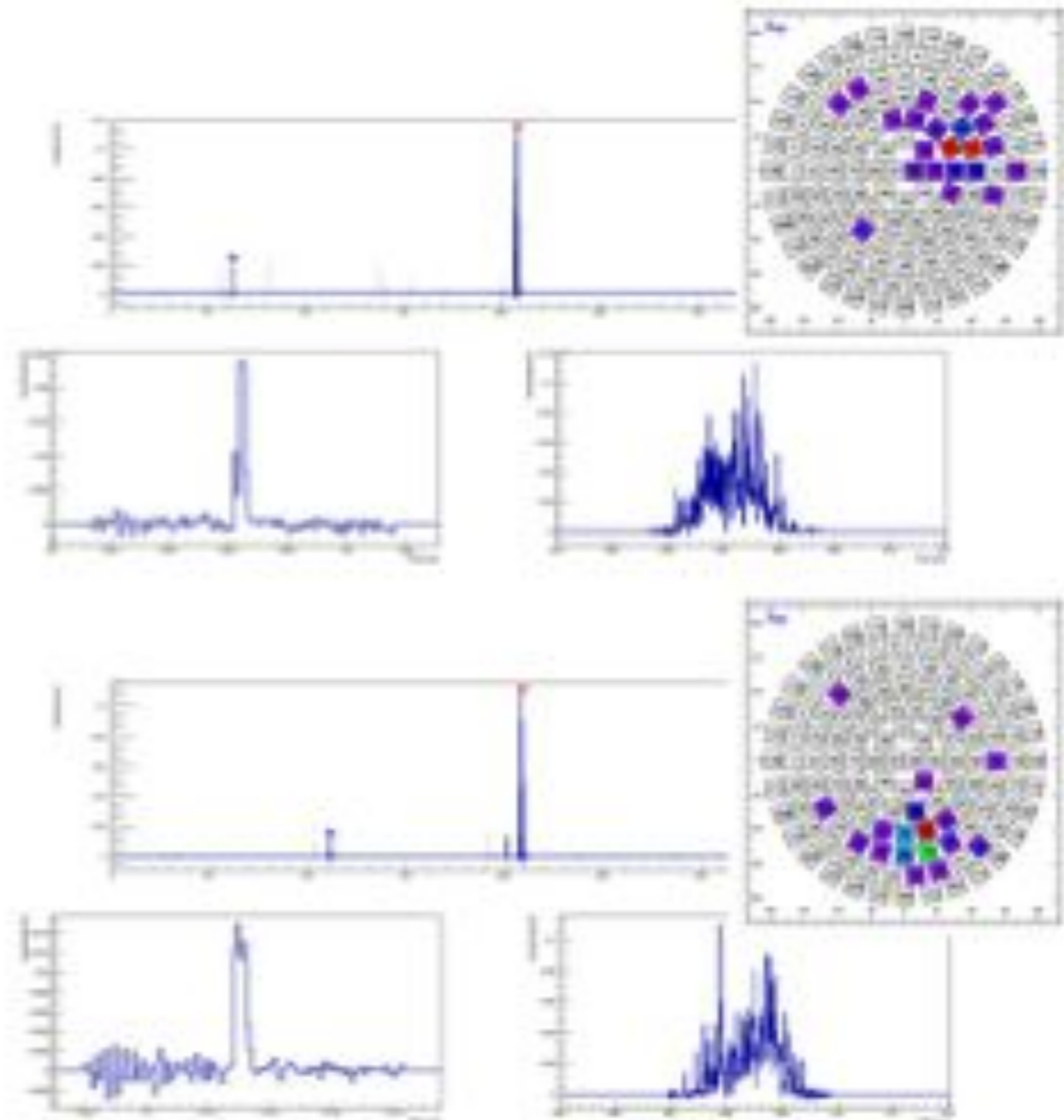
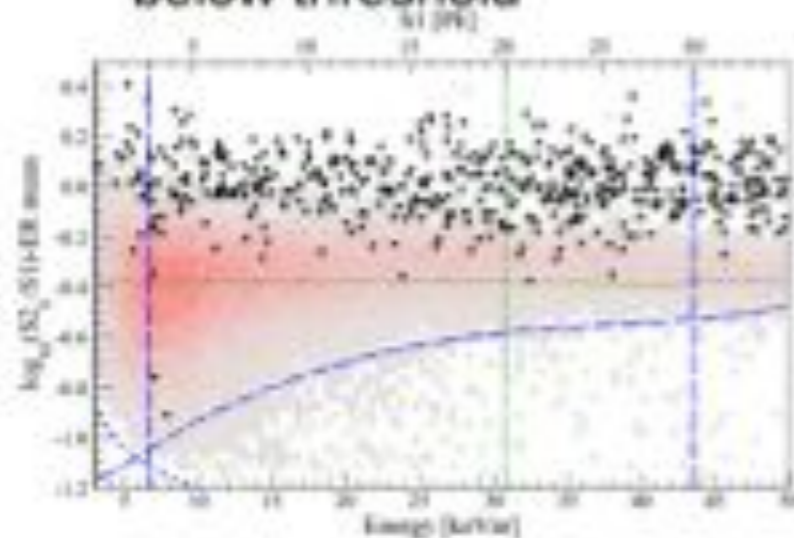
Fiducial mass region:
34 kg of liquid xenon
406 events in total



Signal region:

2 events are observed
 0.79 ± 0.16 gamma leakage events expected
 $0.17^{+0.12}_{-0.7}$ neutron events expected

- visual inspection:
valid waveforms
- at 7.1 keVr and 7.8 keVr
both events between
3 and 4 PE
- rather low wrt the
NR calibration data
- no low S2/S2-events
below threshold



(1.0 ± 0.2) events expected

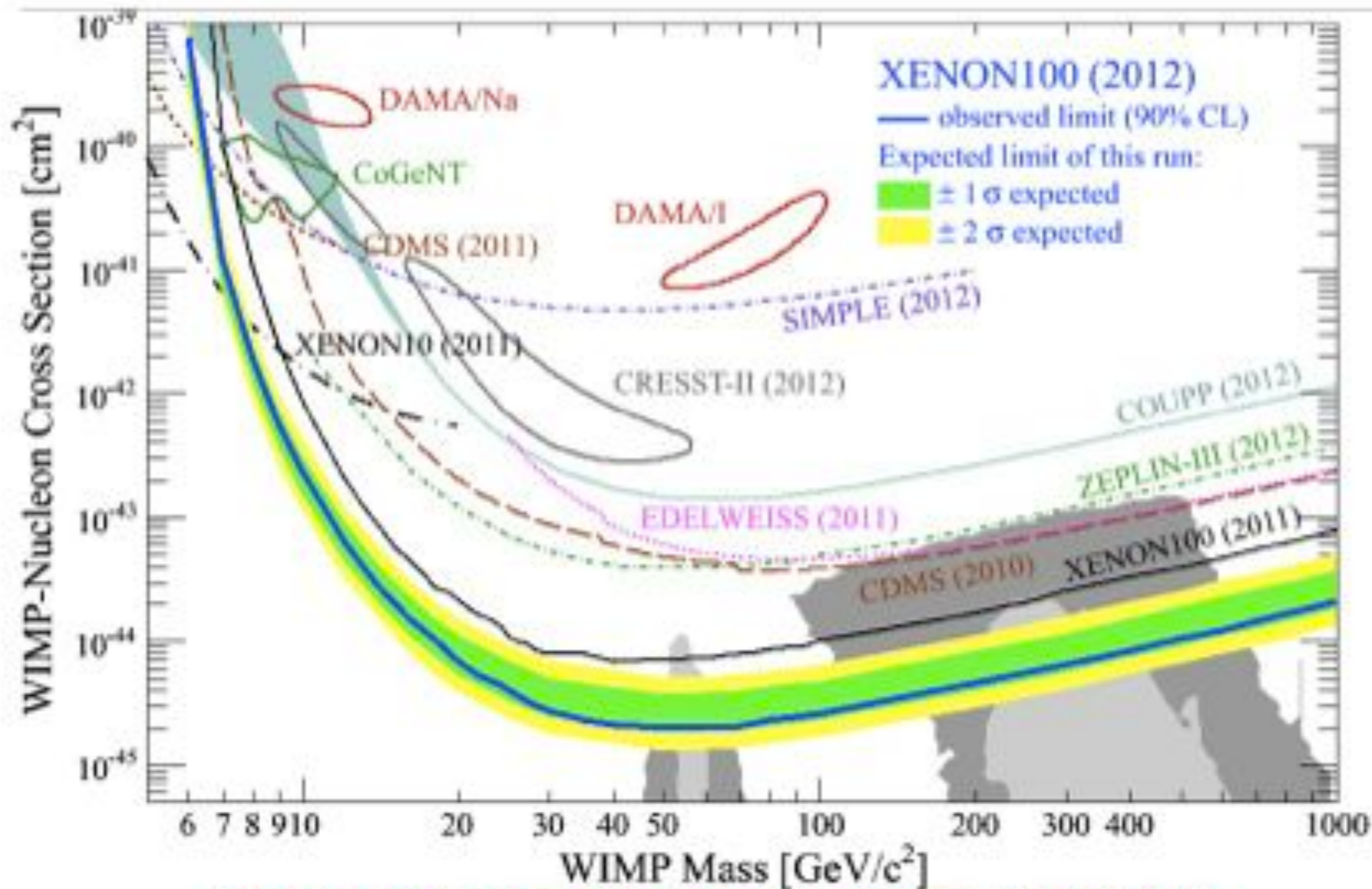
2 events observed

→ 26.4% probability that background fluctuated to 2 events

→ PL analysis cannot reject the background only hypothesis

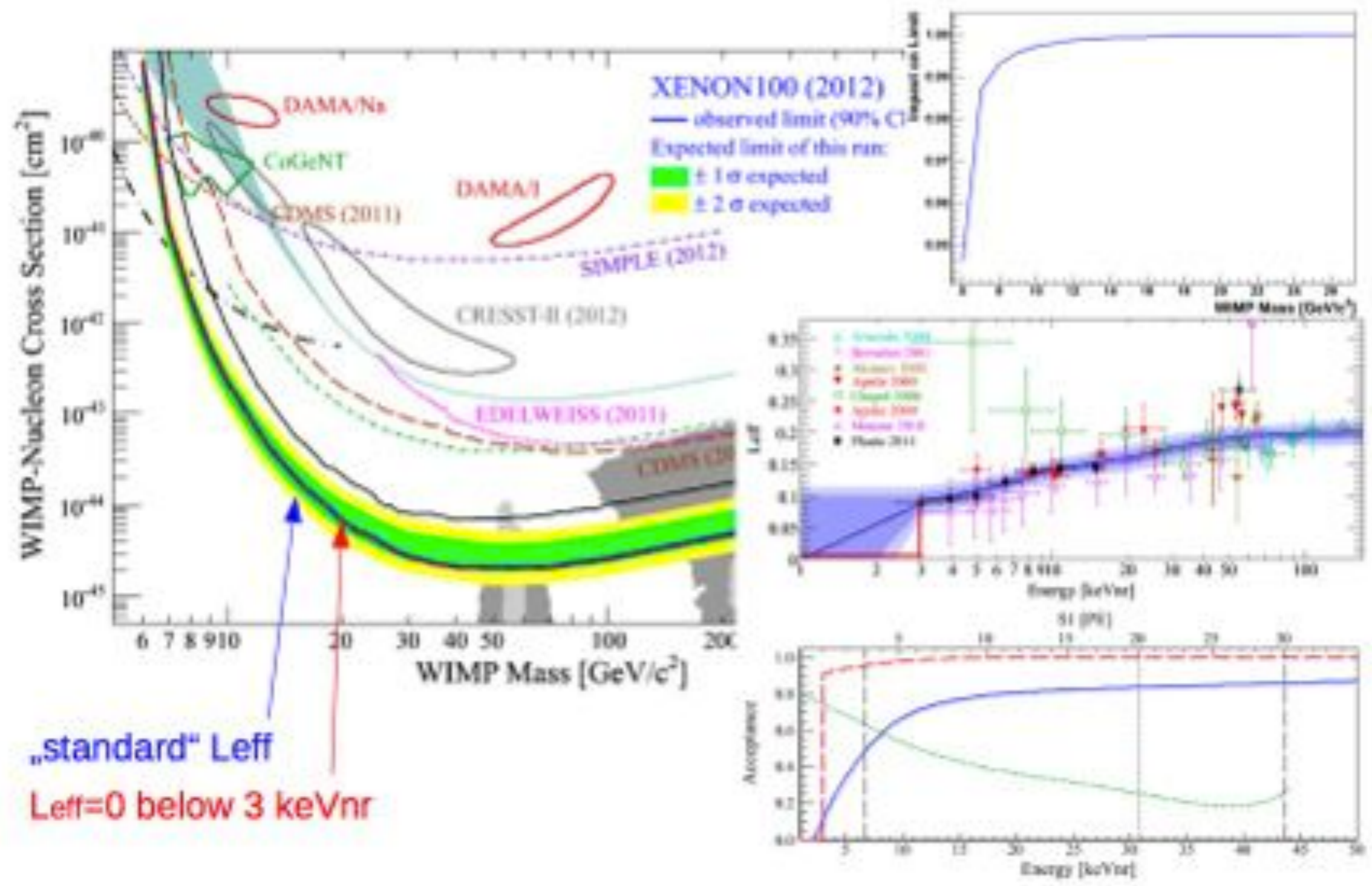
No significant excess due to a signal seen in XENON100 data.

XENON100: New Spin-Independent Results



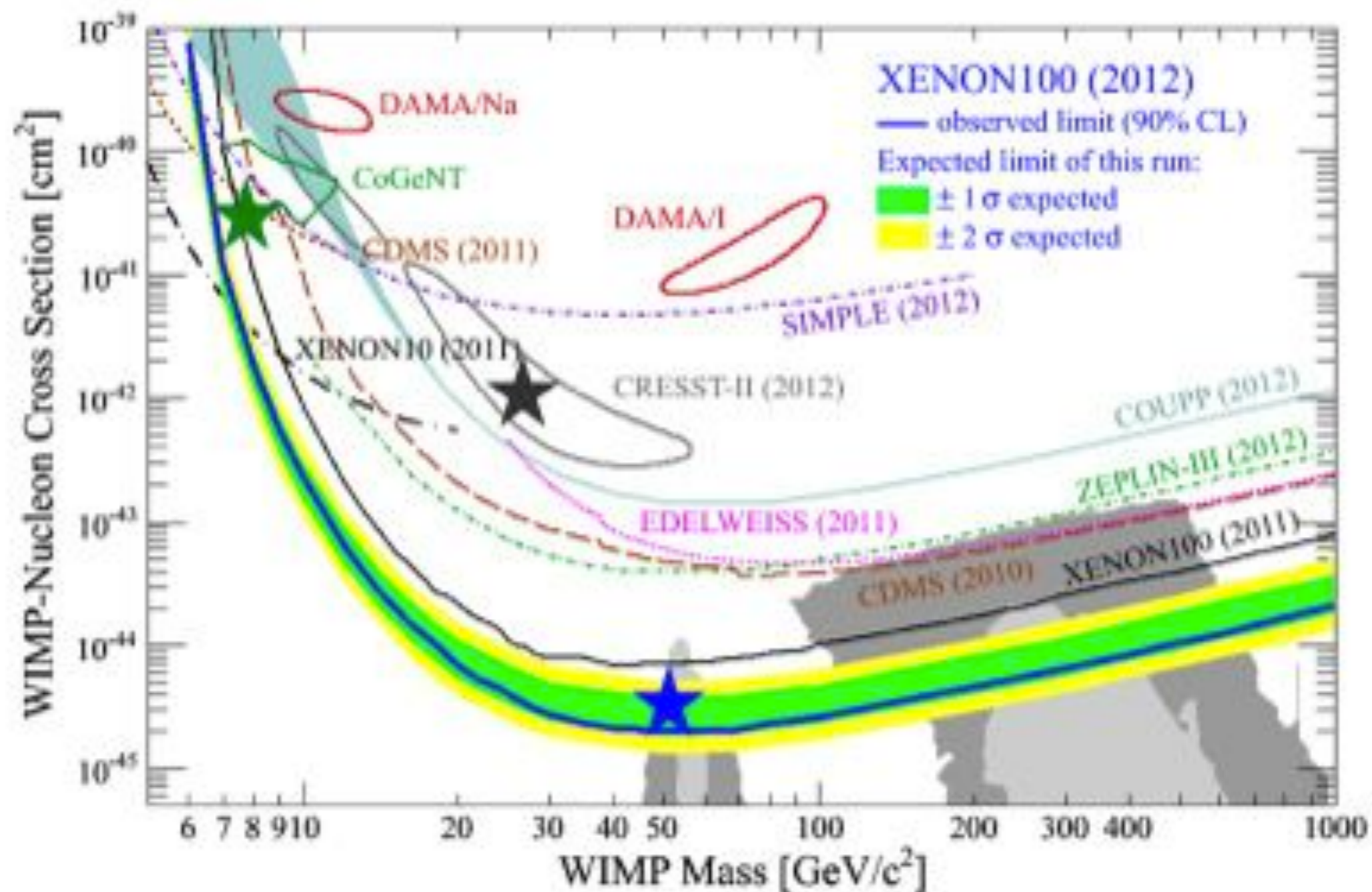
Upper Limit (90% C.L.) is $2 \times 10^{-45} \text{ cm}^2$ for $55 \text{ GeV}/c^2$ WIMP

No Impact of L_{eff} below 3 keVr

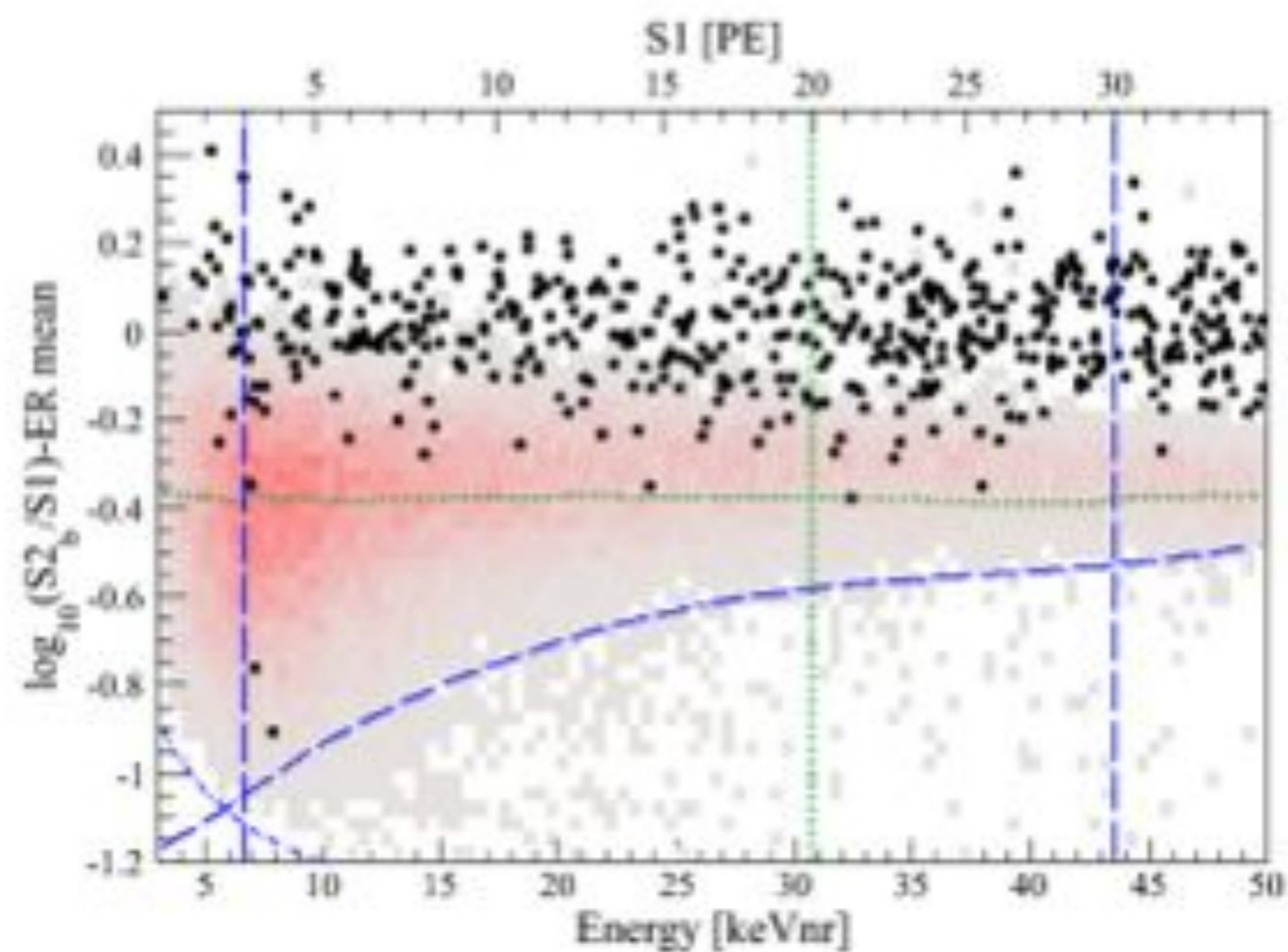


„standard“ L_{eff}
 $L_{\text{eff}}=0$ below 3 keVr

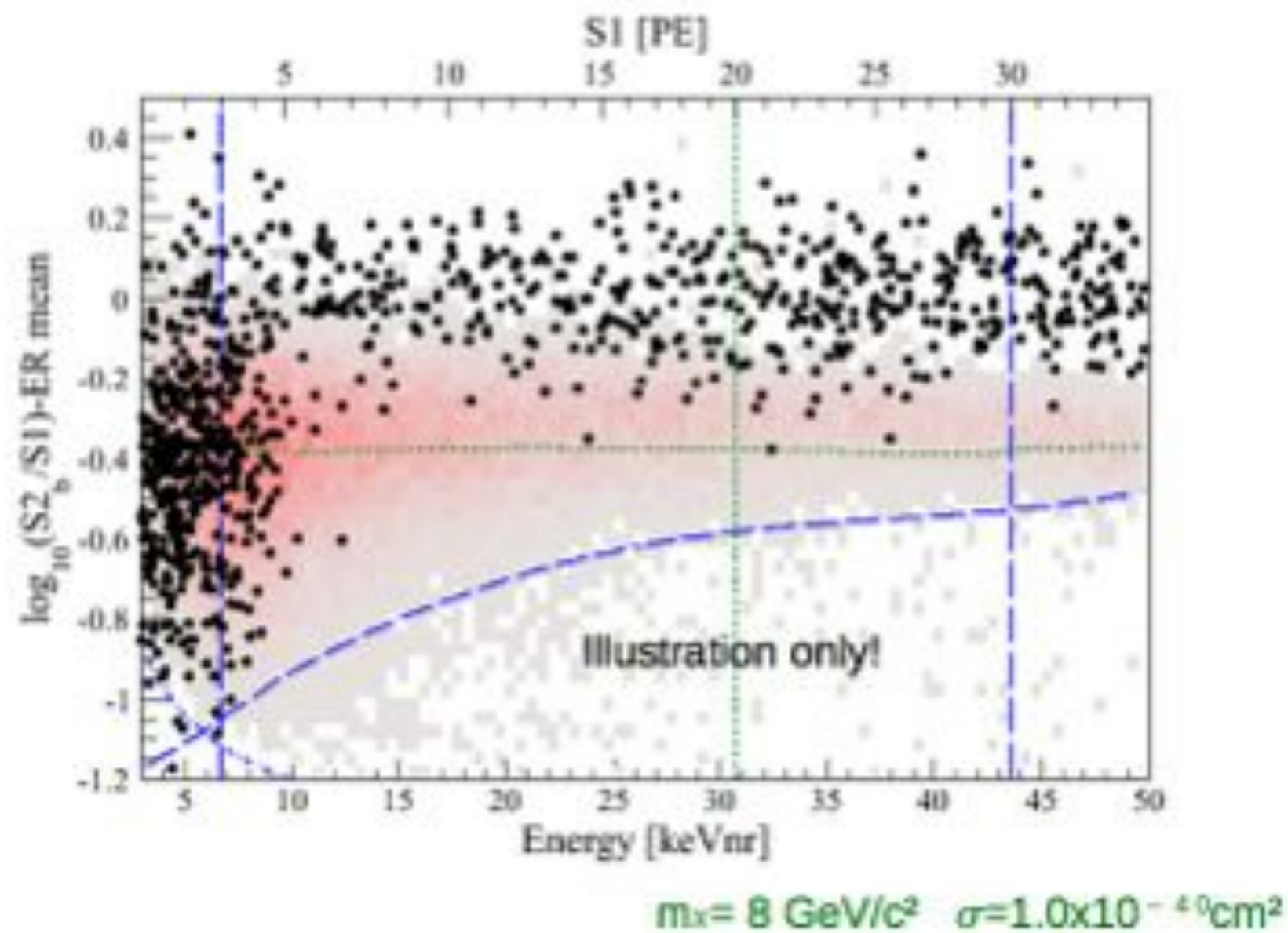
The new XENON100 Limit



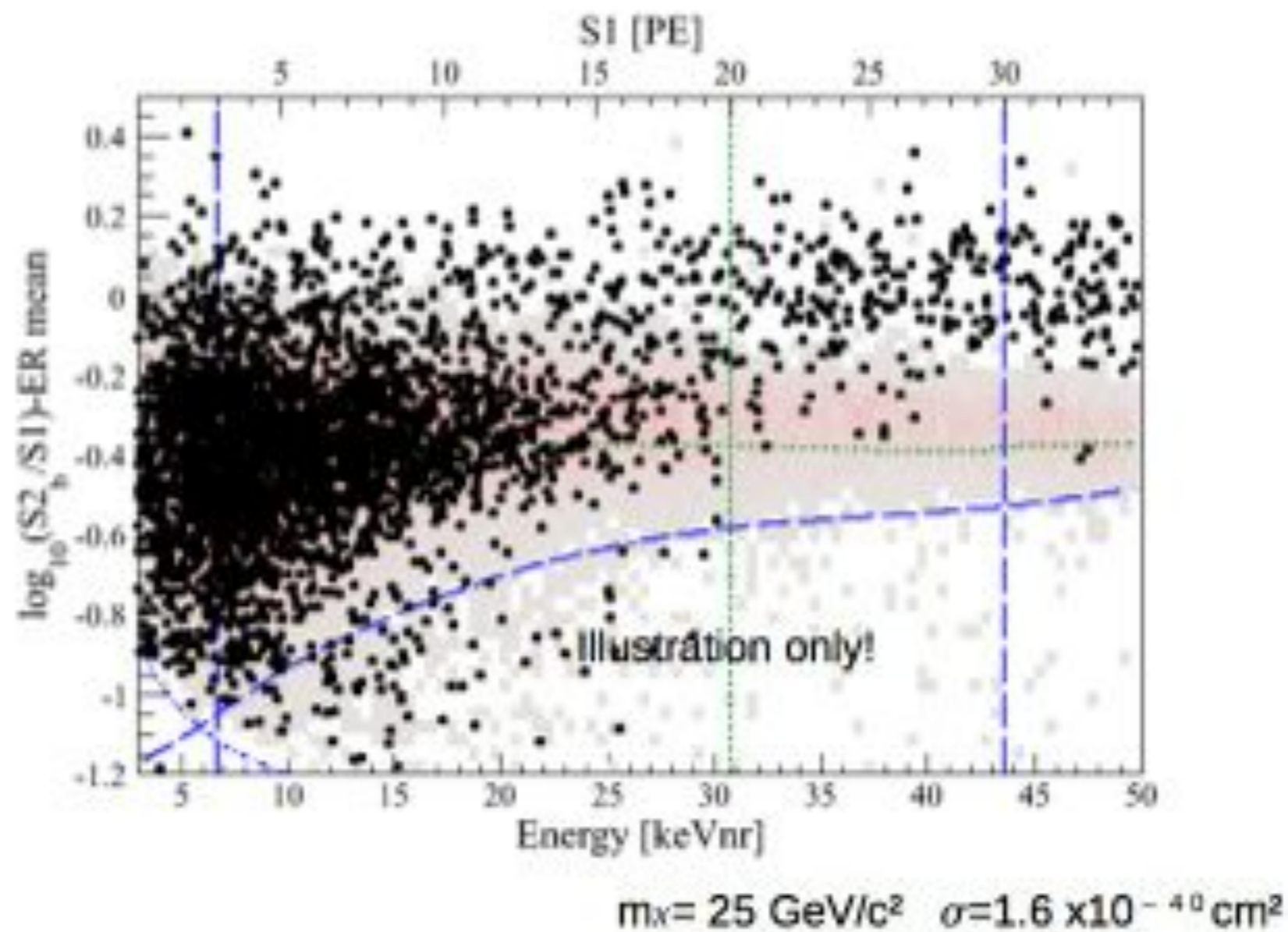
What XENON100 sees...



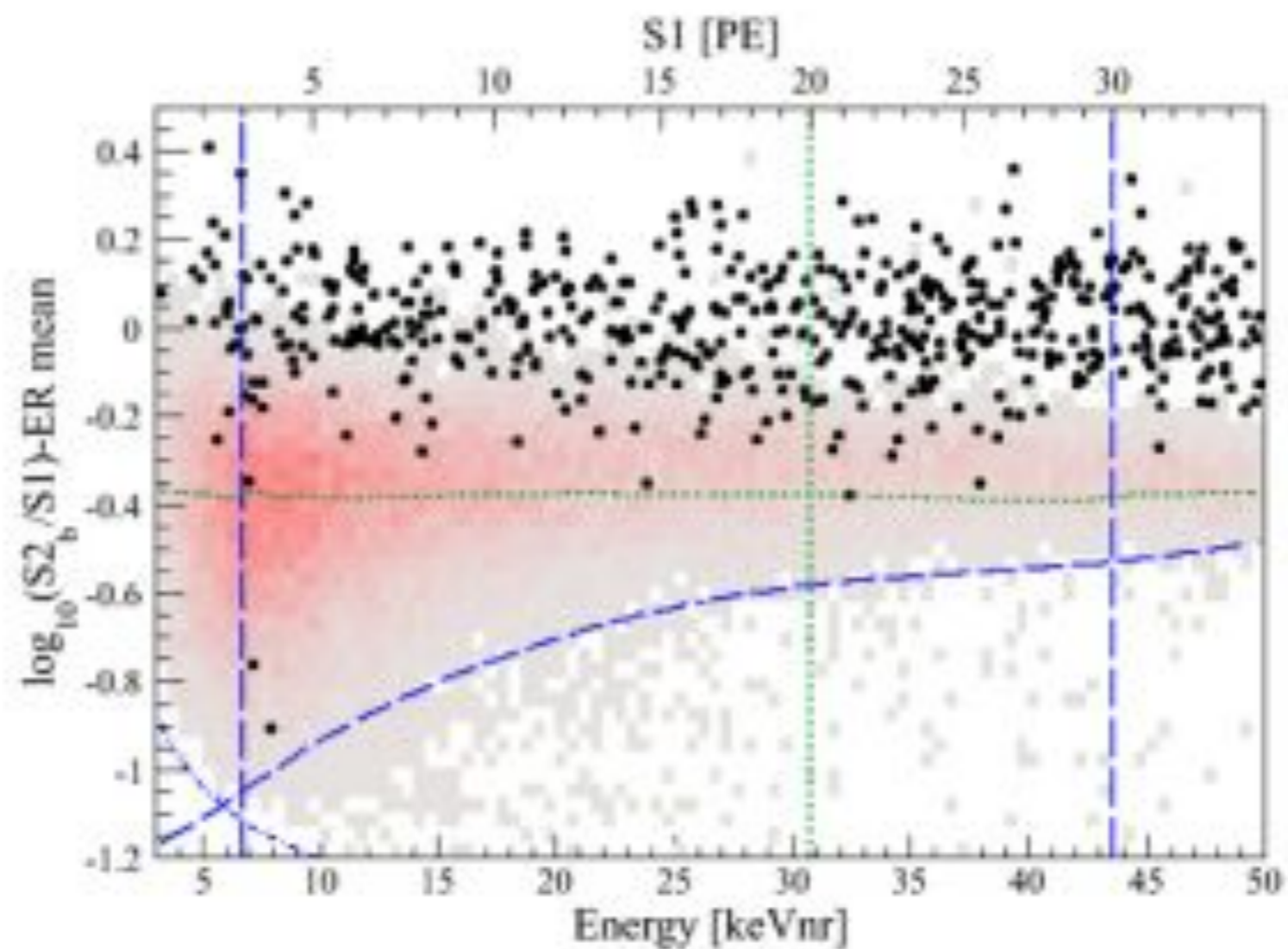
A light mass WIMP...



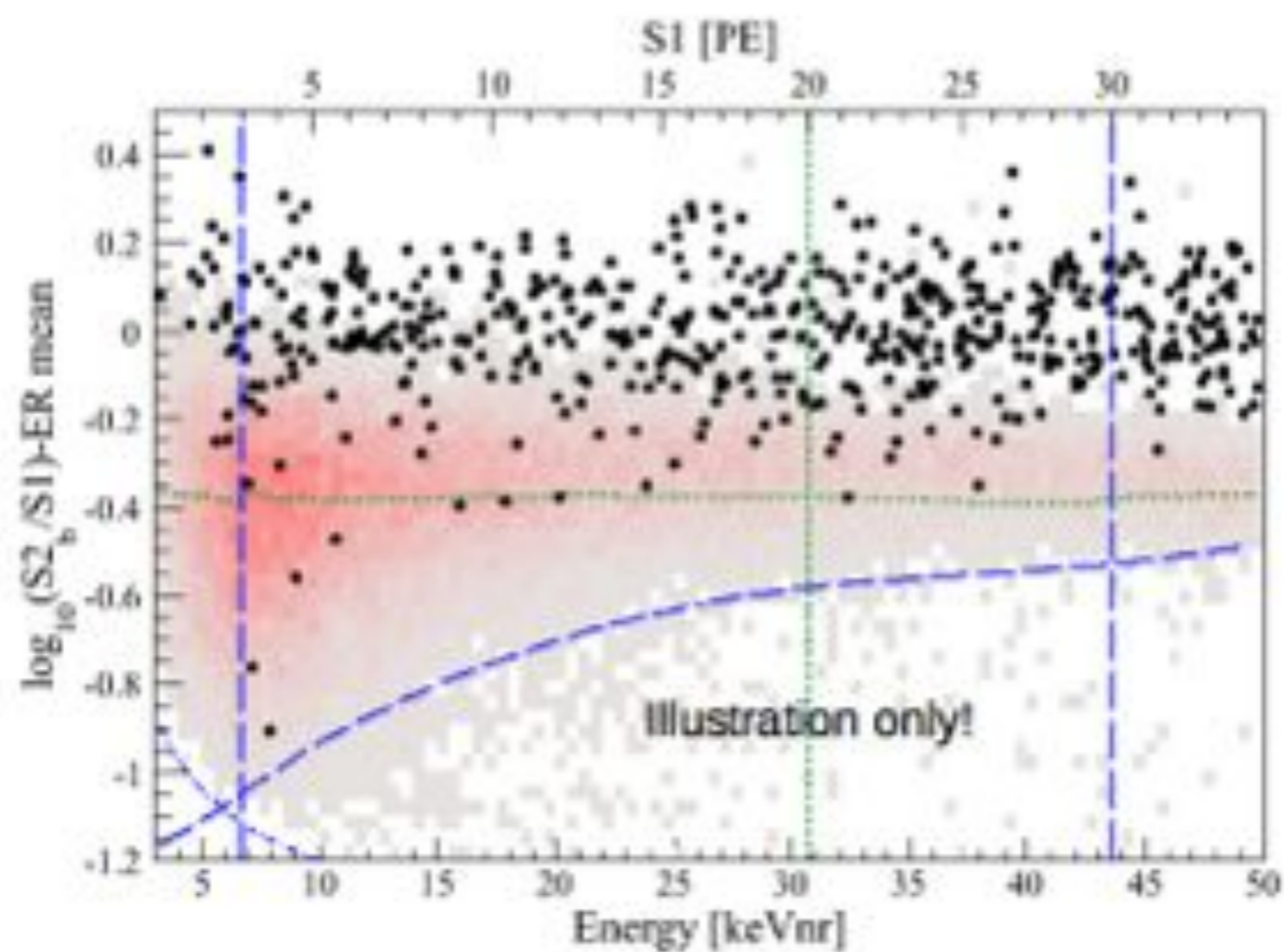
A CRESST-like signal...



What XENON100 sees...

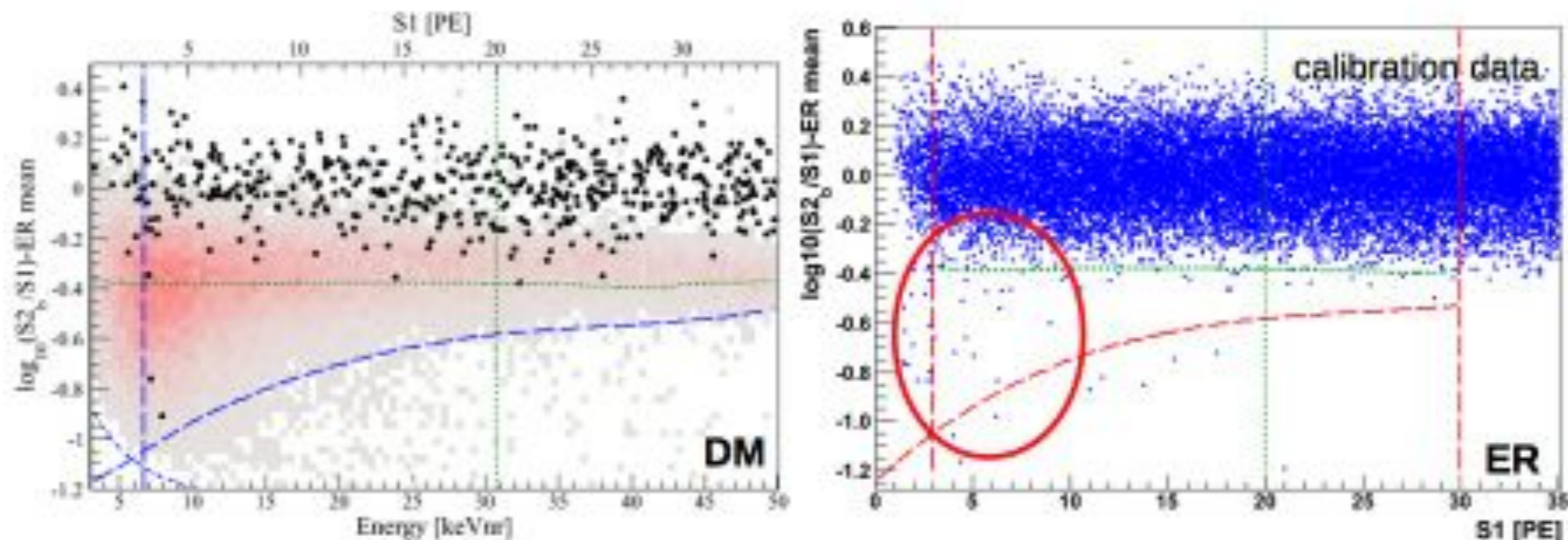


What XENON100 excludes...



$$m_\chi = 50 \text{ GeV}/c^2 \quad \sigma = 3.0 \times 10^{-45} \text{ cm}^2$$

What could the Events be?



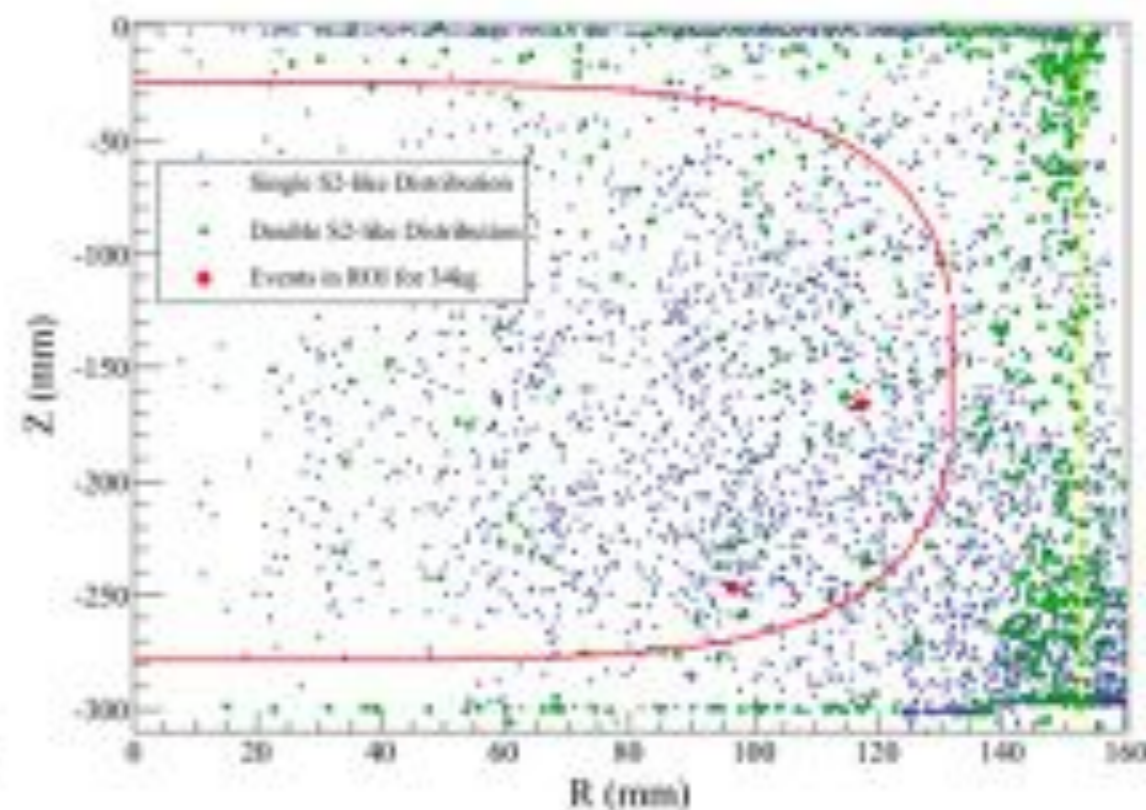
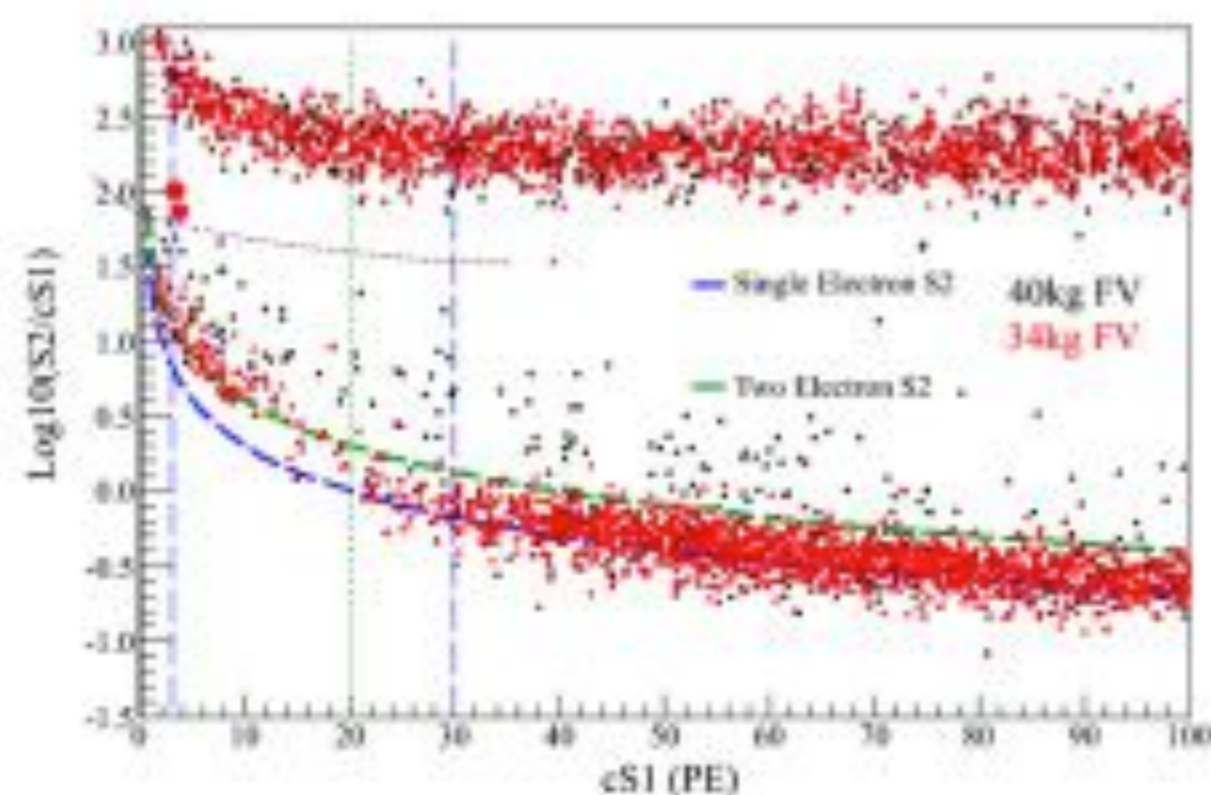
Reminder:

Background is modeled using ER calibration data from Co60 and Th232

This data shows an increased probability for anomalous leakage below ~8 PE

Background prediction depends on the information which is put into the model

Sensitivity to single electrons

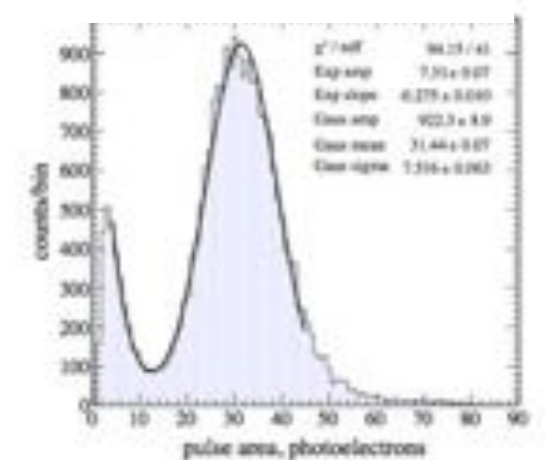
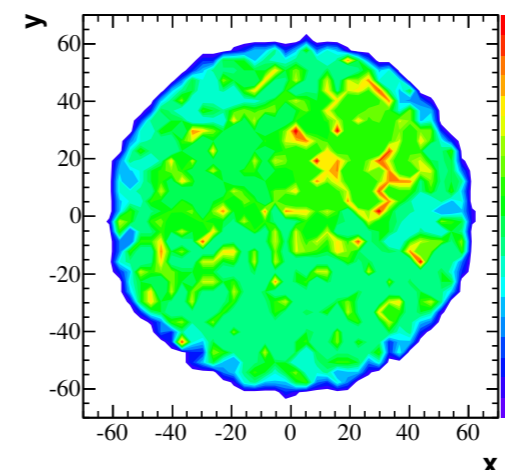
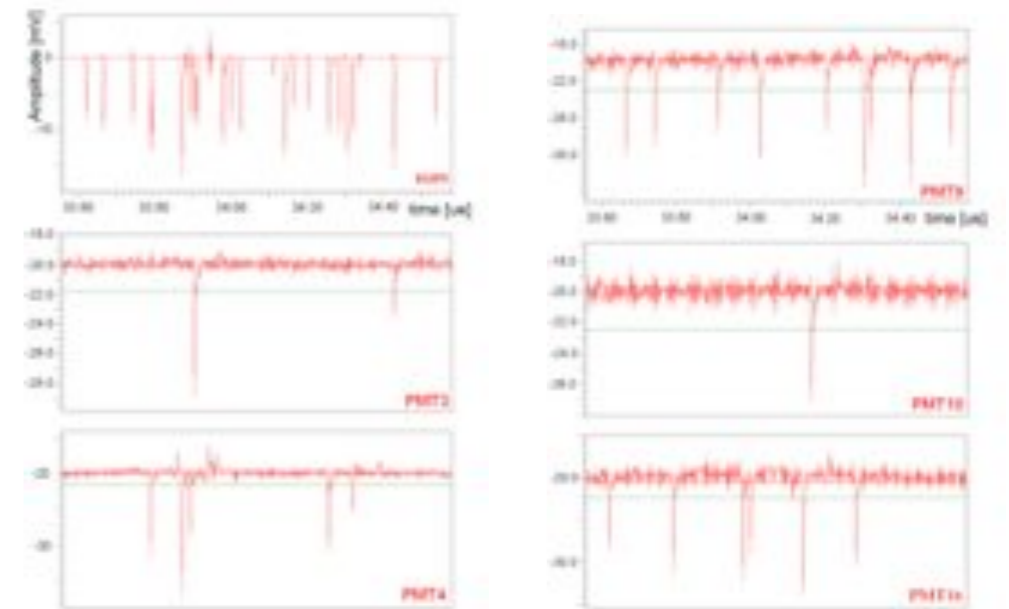
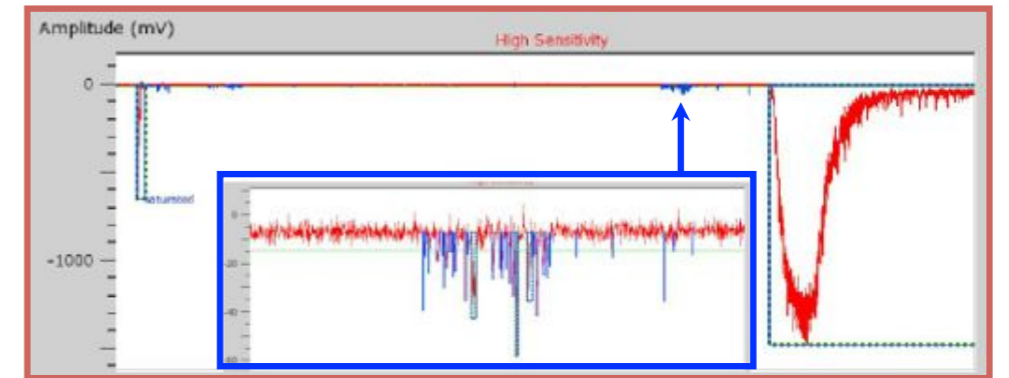


Relaxing the S2 threshold condition ($S2 > 150$ PE)
leads to a band of events at very low $S2/S1$ (below signal range)

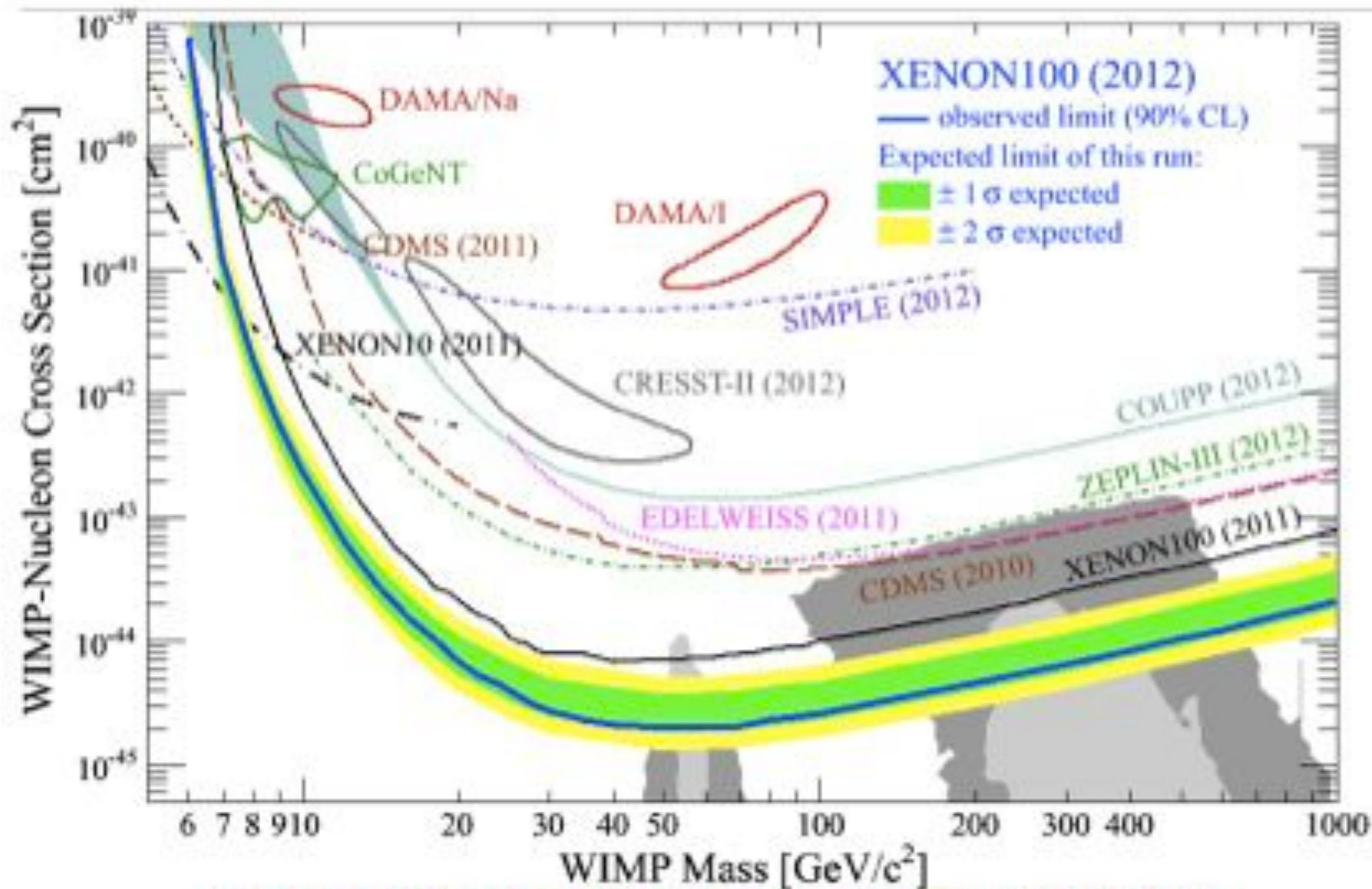
- can the 2 events be in the tail of this band???
- further studies are required
- aim: quantify and put into background model for the next run

(Further) Exploiting the Ionisation Channel

- Resolution of primary scintillation is dominated by photon generation and photoelectron collection statistics
- Single electron detection demonstrated in LXe TPCs
- In ZEPLIN-III, single electrons detected within 36 μ s timeline and with dedicated runs
- Origin:
 - ❖ Photon-induced (post SI): photoionisation and emission from cathode
 - ❖ Spontaneous emission: background related
- Application:
 - ★ Electron lifetime measurement (extremely useful for ton and greater scale detectors)
 - ★ Lower thresholds (~ 1 keV) and superior resolution
 - ★ **Low mass WIMP searches**
 - ★ **Neutrino physics**

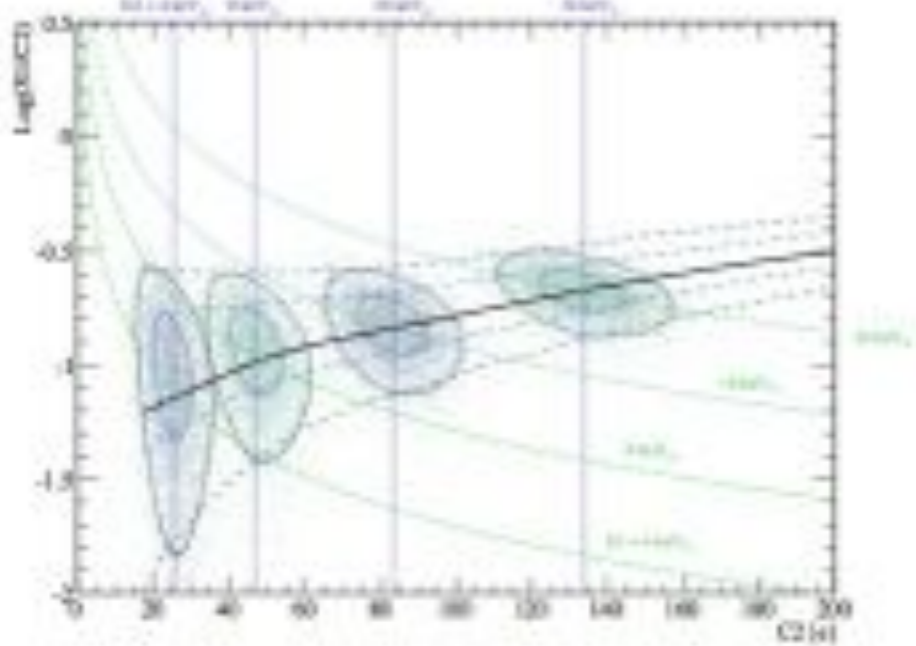
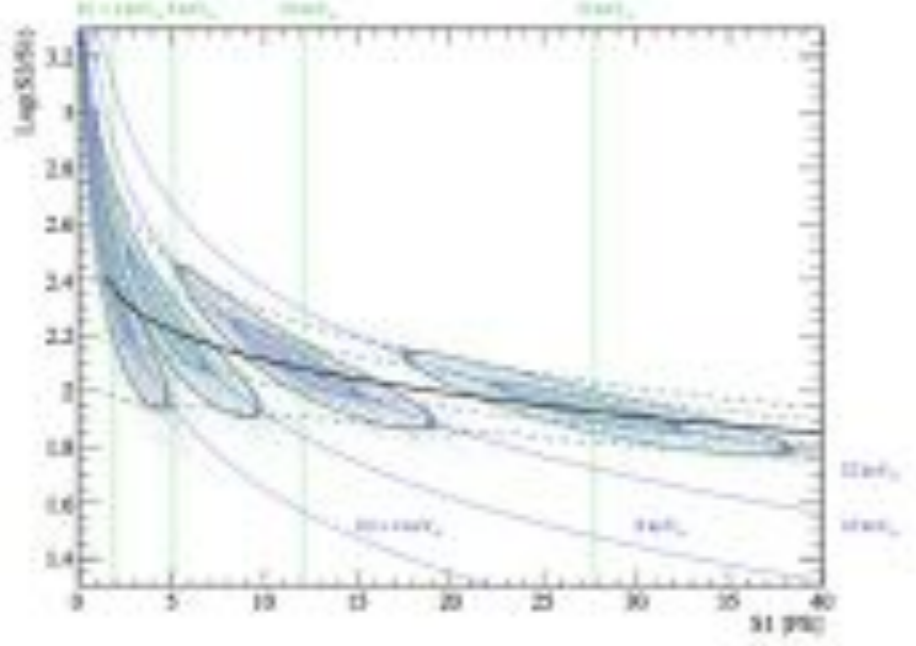
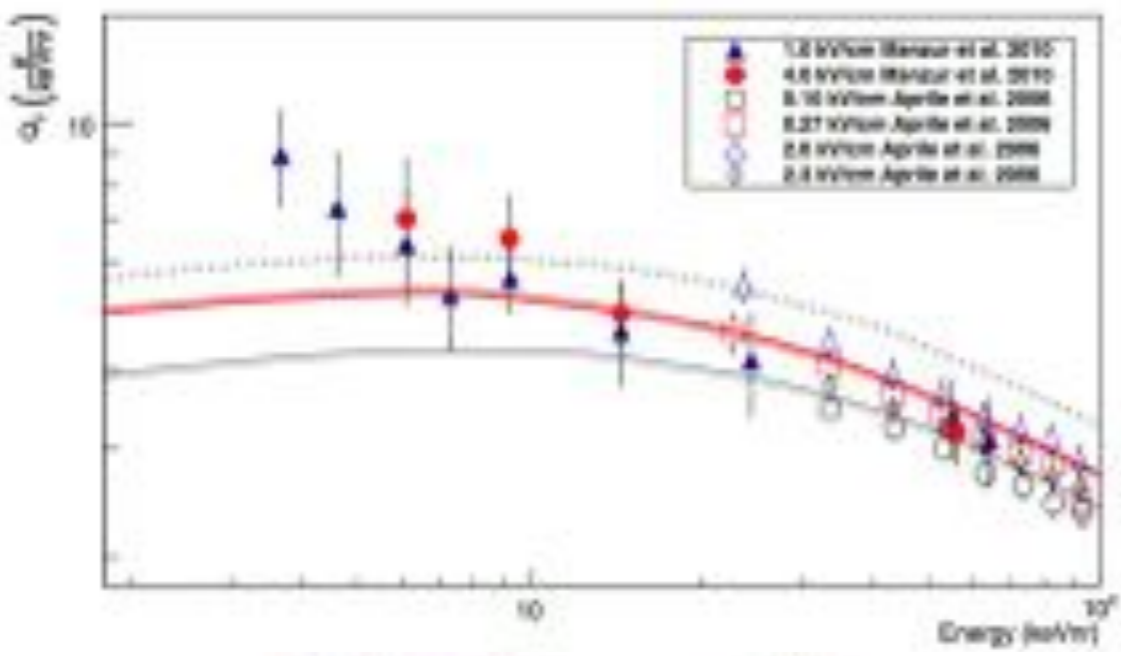


XENON100: New Spin-Independent Results



Upper Limit (90% C.L.) is 2×10^{-45} cm² for 55 GeV/c² WIMP

WIMPS



CNNS

AXIONS

Single electron emission in two-phase xenon with application to the detection of coherent neutrino-nucleus scattering

ZEPLIN-III Collaboration

E. Santos,^{1,2} B. Edwards,² V. Chepel,¹ H.M. Araújo,² D.Ya. Akimov,⁴ E.J. Barnes,⁵ V.A. Belov,⁴ A.A. Burenkov,⁴ A. Currie,² L. DeViveiros,¹ C. Ghag,⁵ A. Hollingsworth,⁵ M. Horn,² G.E. Kalma,² A.S. Kobaykin,⁴ A.G. Kovalenko,⁴ V.N. Lebedenko,² A. Lindote,^{1,2} M.I. Lopes,¹ R. Löcherer,² P. Majewski,² A.St.J. Murphy,² F. Neves,^{1,2} S.M. Paling,² J. Pinto da Cunha,¹ R. Preese,² J.J. Quesby,² L. Reichhart,² P.R. Scovell,² C. Silva,² V.N. Solovov,¹ N.J.T. Smith,² P.F. Smith,² V.N. Stokhanov,⁴ T.J. Sumner,² C. Thorne² & R.J. Walker²

[Journal of High Energy Physics 12 \(2011\) 115](https://arxiv.org/abs/1011.1115)

Expected Sensitivity to Galactic/Solar Axions and Bosonic Super-WIMPs based on the Axio-electric Effect in Liquid Xenon Dark Matter Detectors

S. Arbuckle¹, F. Belluschi, C. Ghag², J. Kahl, K. Jung, A. Lyuboslavski, R. D. Preest, P. Smith, K. Yu³

Department of Physics and Astronomy, University of California, Los Angeles, 481 Portola Plaza, Los Angeles, CA 90095, USA

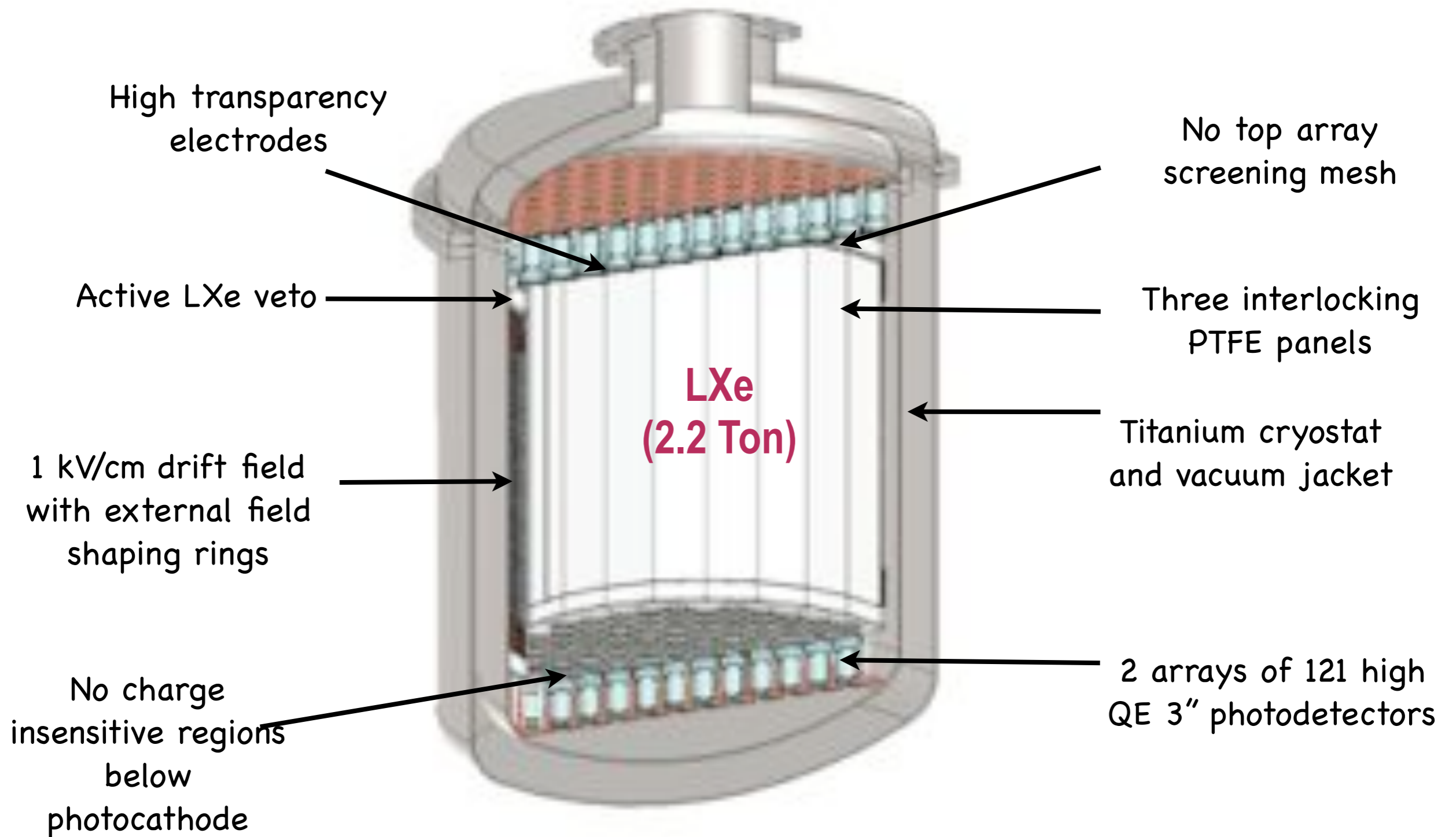
Abstract

We present systematic case studies to investigate the sensitivity of axion searches by liquid xenon detectors, using the axio-electric effect (analogue of the photoelectric effect) on axion atoms. Liquid xenon is widely considered to be one of the best target media for detection of WIMPs (Weakly Interacting Massive Particles which may form the galactic dark matter) using nuclear recoil. Since these detectors also provide an extremely low radioactivity environment for electron recoils, very weakly-interacting low-mass particles (< 100 keV/c²), such as the hypothetical axion, could be detected as well – in this case using the axio-electric effect. Future ton-scale liquid Xe detectors will be limited in sensitivity only by irreducible neutrino background (primarily solar neutrinos and the double beta decay of ¹³⁶Xe) in the mass range between 1 and 200 keV/c². Assuming one ton-year of exposure, galactic axions (as non-relativistic dark matter) could be detected if the axio-electric coupling g_{AE} is greater than 10⁻¹² at 1 keV/c² (or 10⁻¹¹ at 200 keV/c²). Below a few keV/c², and independent of the mass, a solar axion search would be sensitive to a coupling g_{AE} ~ 10⁻¹². This limit will set a stringent upper bound on axion mass for the DFV and DFVX models for the mass ranges m_A < 0.1 eV/c² and < 30 eV/c², respectively. Vector-tensor dark matter could also be detected for a coupling constant a'/v > 10⁻¹² (for mass 1 keV/c²) or > 10⁻¹¹ (for mass 200 keV/c²).

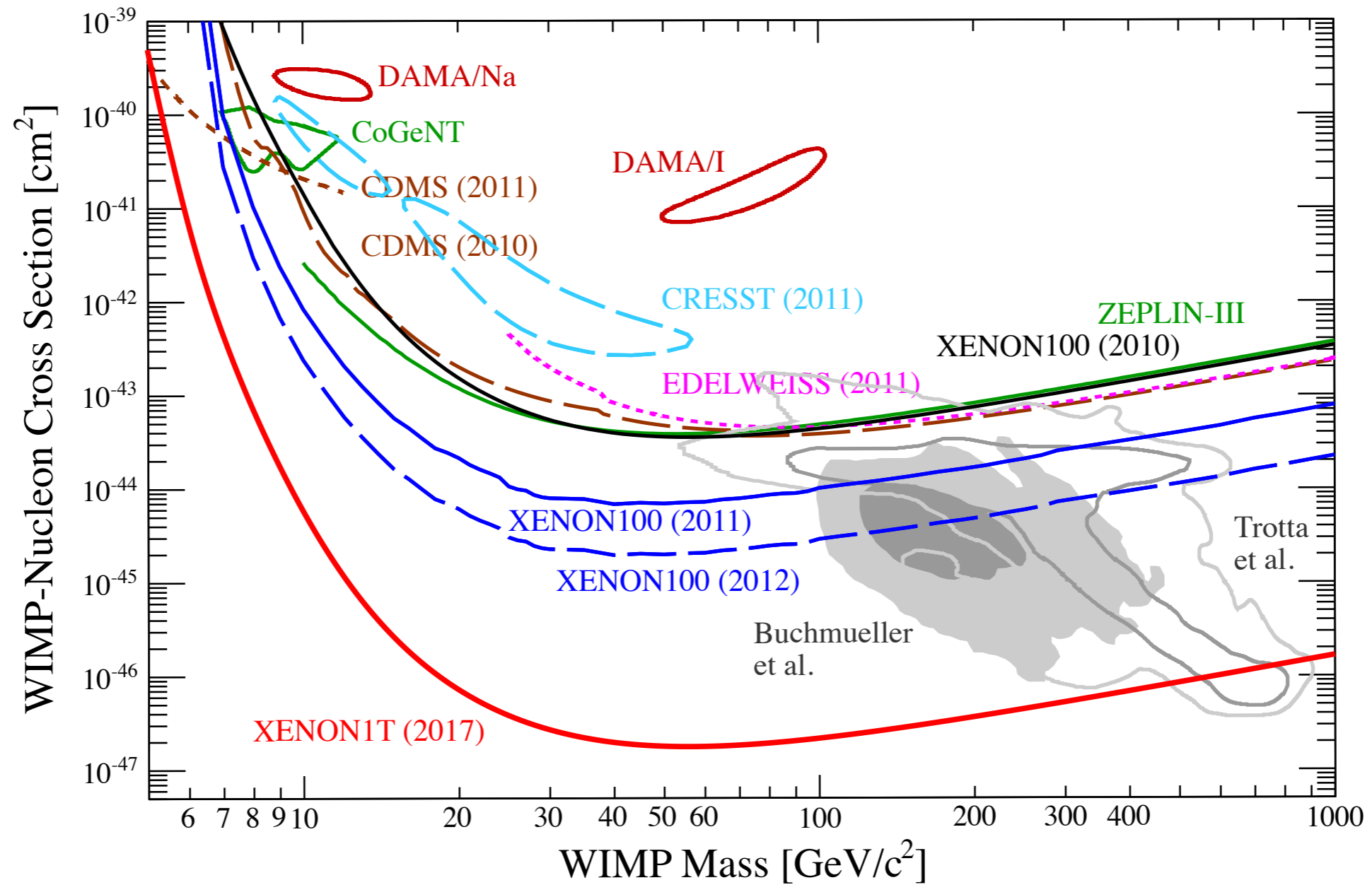
<http://arxiv.org/pdf/1209.3810.pdf>

1. Very Brief Intro to Dark Matter and Direct Detection
2. The LXeTPC & XENON100
3. Latest Results
4. The Next Generation

The Next Step: XENONIT



Scaleability has been demonstrated repeatedly - gets easier (no performance loss) as we get bigger!



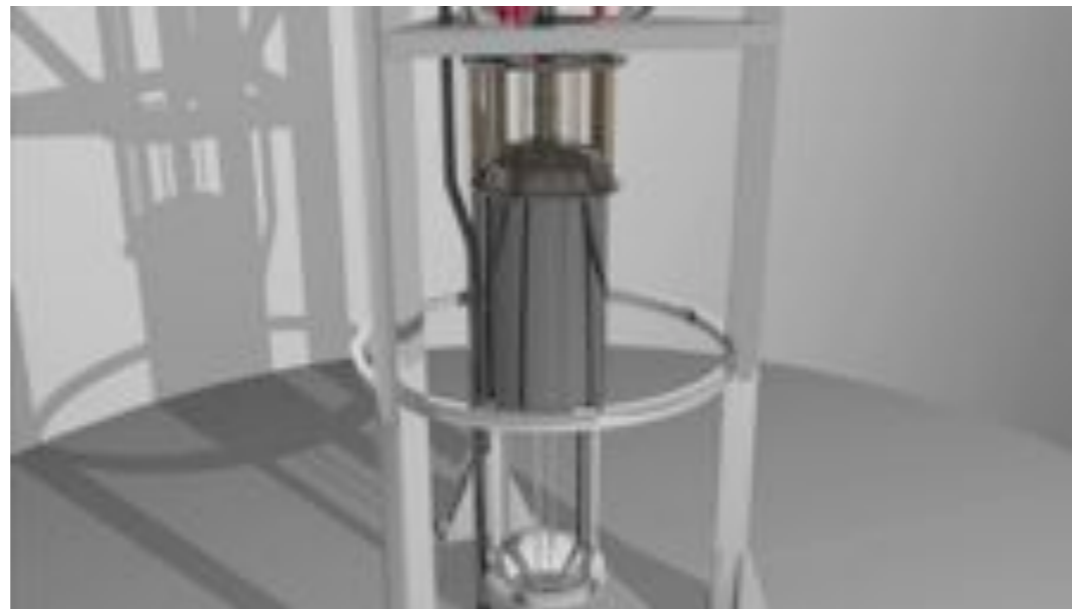
1 Tonne Fiducial Mass
2 Year Exposure (~2017)



Homestake mine
South Dakota



Davis Cavern (5th May 2011)
4850 ft depth



Dec 2011

**World
leader in
2013**

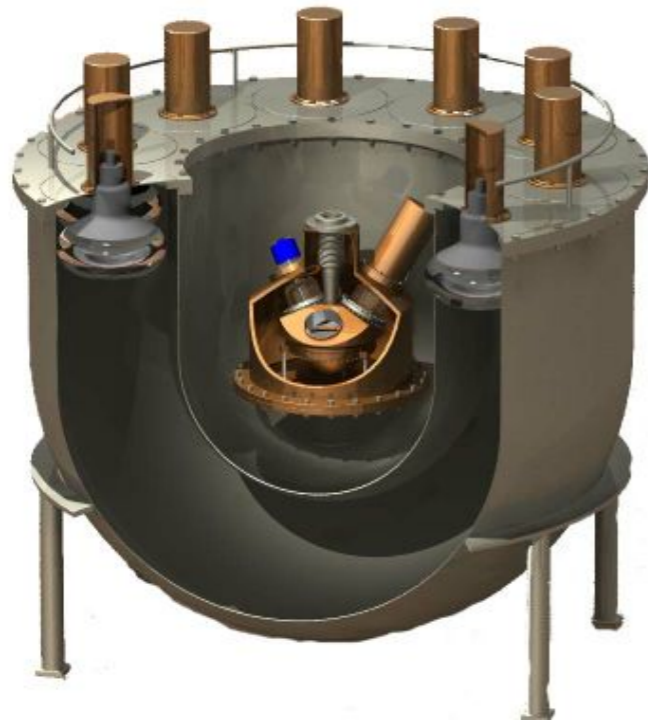


Sept 5th 2012
Water Shield and lab ready for LUX!



Status: Underground commissioning

The ZEPLIN Programme at Boulby



ZEPLIN I

Single phase, 3 PMTs, 5/3.1 kg
Run 2001-04
Limit: $1.1 \cdot 10^{-6}$ pb

Single-phase



ZEPLIN II

Double phase, 7 PMTs,
moderate E field, 31/7.2 kg
Run 2005-06
Limit: $6.6 \cdot 10^{-7}$ pb

The first 2-phase LXe Dark Matter
detector!



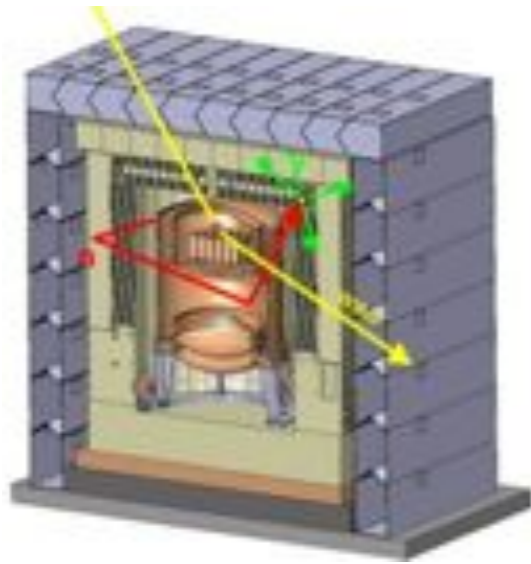
ZEPLIN III

Double phase, 31 PMTs,
high E field, 10/6.4 kg
Run 2009-11
Limit: $3.9 \cdot 10^{-8}$ pb

Europe's most sensitive SI
World's best WIMP-neutron SD

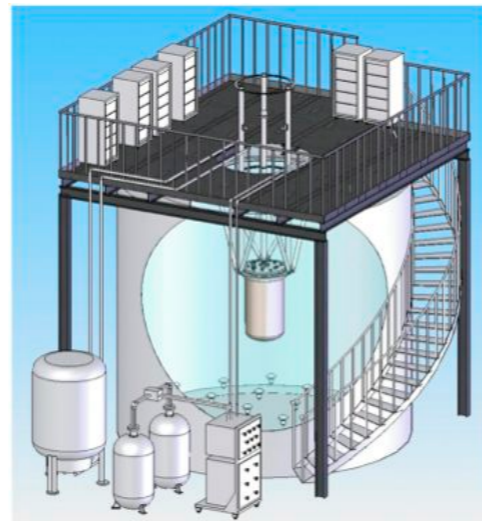
LUX-ZEPLIN (LZ)

ZEPLIN-III



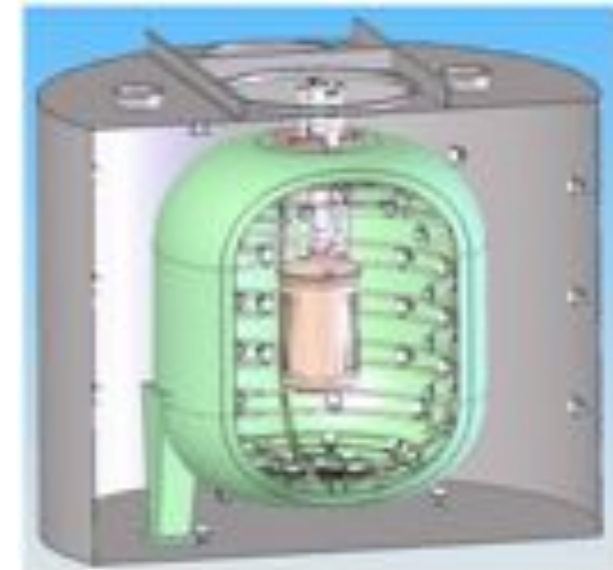
6 kg LXe

LUX



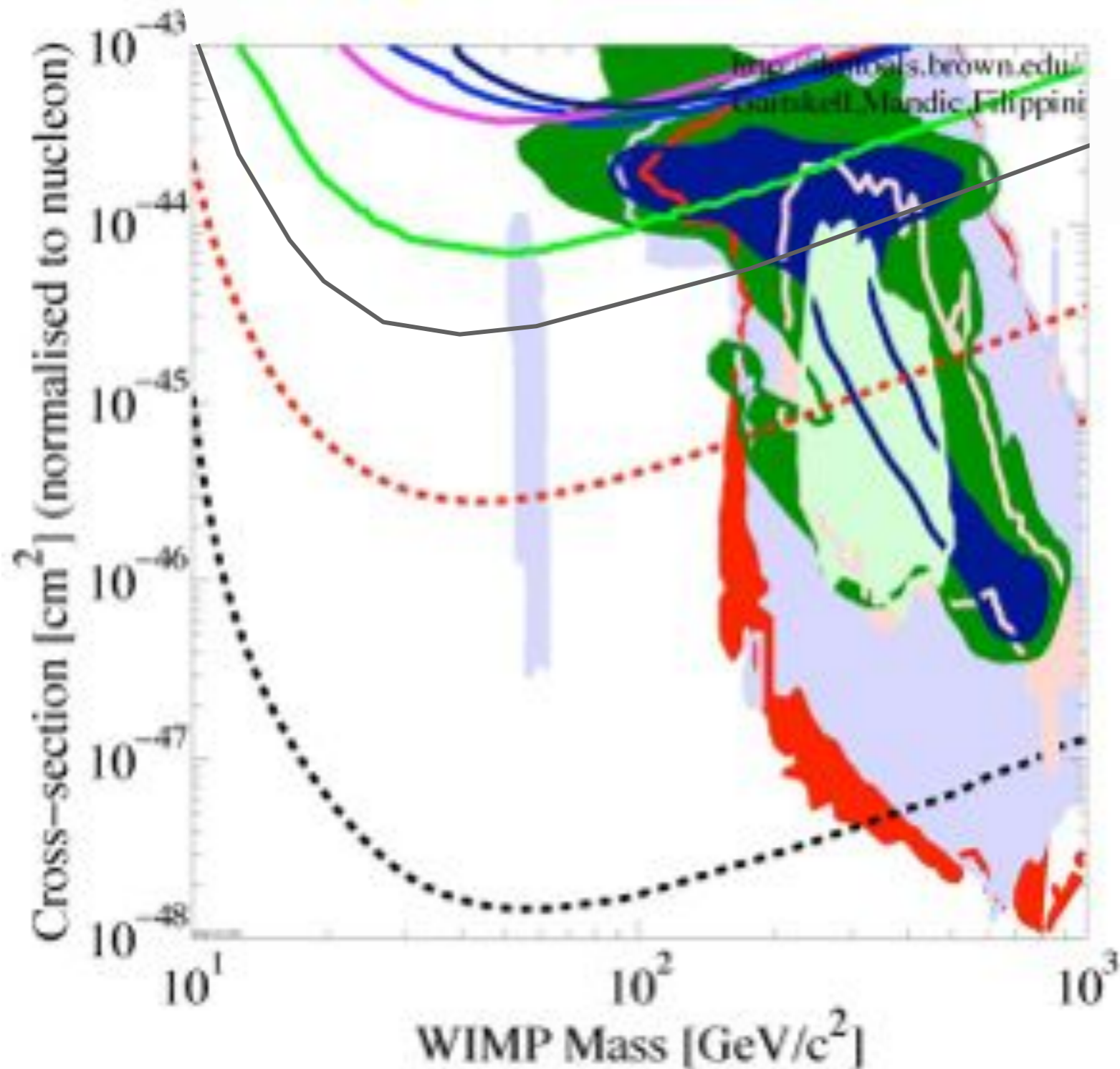
100 kg

LZ



5,000 kg

- Merger of the UK-led ZEPLIN and LUX progressive programmes
- Scaling the proven, world-leading technology that UK pioneered
- SI WIMP-nucleon cross-section sensitivity to $\sim 10^{-48} \text{ cm}^2$



Elastic scattering SI cross-section

Results

ZEPLIN-III 2011 (magenta)

XENON100 2011 (green)

XENON100 2012 (grey)

EDELWEISS II 2011 (dark blue)

CDMS-II 2010 (blue)

Projections

LUX (red dash)

100 kg fiducial x 300 live days

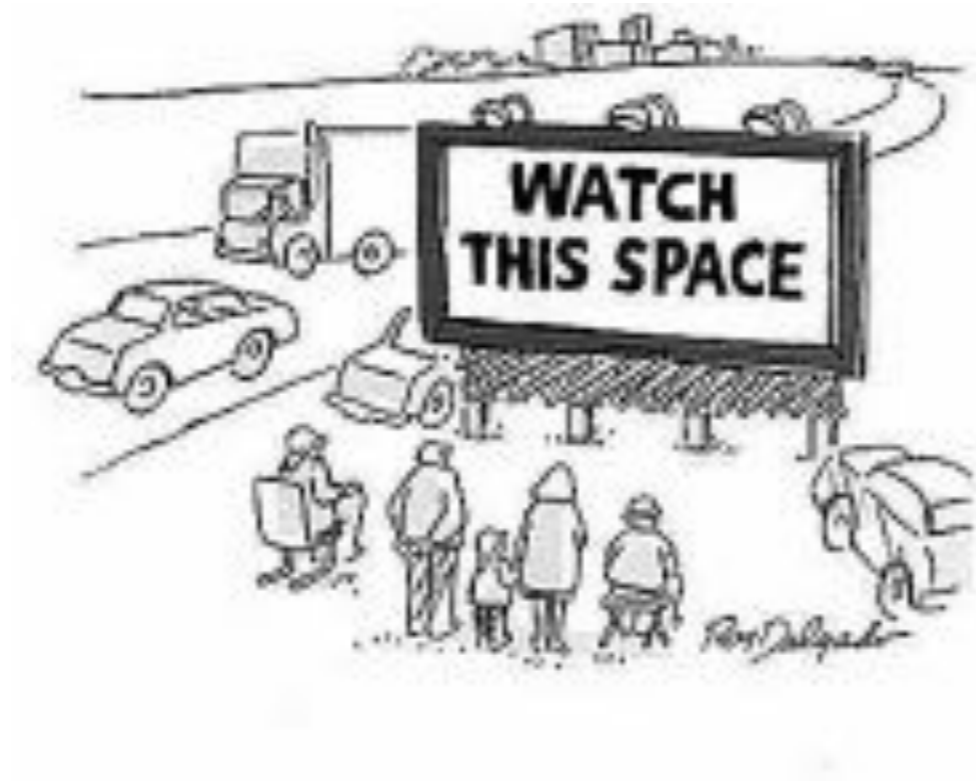
LUX-ZEPLIN (black dash)

5-tonne fiducial x 1,000 live days

Summary

- LXeTPCs, pioneered by the ZEPLIN and XENON collaborations have rapidly accelerated the race for WIMPs, excluding **3 orders of magnitude** in WIMP-nucleon cross-section over the past decade
- Scaling detectors **lowers background**, but does not harm threshold, discrimination, or event vertex reconstruction
- Demonstrated stability over periods of **years**; most construction and operational techniques perfected
- XENON100 achieved sensitivity an **order of magnitude** better than any competing experiment
- Exploiting the ionisation channel lowers threshold from existing 6-7 keV down to **1 keV**
LXeTPCs perform 'broadband' Dark Matter searches - not just the SUSY neutralino
- Next up is LUX, to become the **world leader in 2013**
- The tonne scale 'G2' Experiments, XENON1T (1.1T) and LUX-ZEPLIN (5T), will build on the LXeTPC track-record to deliver sensitivity for a robust and statistically significant **first discovery!**

Exciting times ahead....



Thank you all for listening!